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GEOSCIENTIFIC INTERPRETATION OF MATERIAL RELATING TO THE REGION BETWEEN THE DANUBE AND THE TISZA IN HUNGARY, OBTAINED BY REMOTE SENSING FROM THE LANDSAT SATELLITES

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1. Application of the regional characteristics in the evaluation

The remote sensing procedures are methods that have been well tried internationally for the geoscientific processing of observation material, and particularly that obtained from the various satellites. We have now made use of these procedures with a view to the geoscientific interpretation of a regional unit in Hungary. One of the main aims of our work was to settle the disputed question of the extent to which remote sensing information can be usefully employed in the geoscientific clarification of lowland areas covered with young sediments. For purposes of documentation, the region between the Danube and the Tisza was chosen for two reasons: (a) no-one has previously seen great possibilities in the interpret ation of this plain region, and accordingly through attempts to evaluate it have not been made to date; (b) we wished to demonstrate that even regions that are very poor in relief configurations and hydrographic networks may contain morphogenetic features which are revealed by remote sensing and which are in a causal correlation with the structuralgeological characteristics and concealed movement tendencies of the deeper lithosphere.

The primary aspect of our work was to check on any surface morphological, hydrogeographical and petrofaciological reflections of potential hydrocarbon-bearing structures and still undiscovered sources of raw materials for the construction industry in this region.

Secondary research aims involved the neotectonic and geomorphogenetic analysis of the region; the differentiation of areas of fluviatile erosion and sediment accumulation from areas of aeolian erosion and accumulation; the tracing of generations of drift sand forms; the demarcation of the limits of the present sodic areas and the thin sheet-sands deposited on the loess layers; and the discovery of any traces of dead and buried river beds and peaty areas.

Unfortunately, the foreign experience so far has been that under lowland conditions satellite pictures do not provide the otherwise customary information on those deep-structural correlations which are particularly marked in the strike directions of the strata trends in uncovered terrains and in hilly and mountainous areas possessing denudational relief; in the systems of valley networks; in the relief configuration itself and in the contours of the water network; or even in the degree of determination of the petrological characteristics. For this reason, interpretation schemes with a confirmed deep-structural information content have not previously been available from elsewhere with regard to the young plain surfaces of sediment-collecting basins filled up with thick fluvial and in places aeolian sediments, similar to the situation in Hungary. In connection with procedures applicable to the geological and geographical conditions of the region between the Danube and the Tisza, there simply does not exist any theoretical methodological background which would help in the solution of our objective. Thus, it is understandable that the interpretation of satellite photographs of the region between the Danube and the Tisza comprises an extremely problematical and methodologically new task. This is especially the case as regards the possibility of revealing any deep structures suitable for hydrocarbon storage and areas of occurrence of construction industry raw materials at greater depths under the surface. It is a task which compels us to say that everything we have attempted in the interest of making progress towards the primary objective in our programme has in essence been the first uncertain step along a completely new and untrodden road.

The approach to the secondary objectives may be considered to be much simpler, as the reliability of the satellite information is controlled here by structural, petrographic, morphologic and hydrologic features appearing on the surface, which can thus be observed empirically. However, it was also hoped that our investigations would settle the question of whether in fact the arguments of the satellite information must in all cases be made to conform to the geological system of values based on the traditional data.

At any event, on the basis of the satellite pictures of the region between the Danube and the Tisza it appears that the mapping geologists at times did not employ a sufficiently uniform definition key to denote the sediment facies of the region. At the same time, however, it has also emerged that satellites too are unable to sense numerous existing differences in petrographic quality, the certain differentiation of which is only a simple routine task on the ground. As a consequence of these contradictory findings, even in the early stages of our research it had to be decided that the only appropriate procedure for assessment of the questions relating to the secondary objectives was to treat the satellite material merely as supplementary information, and to subject it to complex analysis in conjunction with the material of target maps prepared by the traditional methods.

The determining principle behind the course of the entire research work was the conception that *the present geographical picture of the surface is only a momentary state in the history of the geographical development; although a large proportion of the earlier events in this history are recorded in the subsurface petro- and morphofacies, they are nevertheless in close determining contact with the natural geographical conditions of the present age.* According to this conception, therefore, in the young filled basins particular attention must be devoted to the clarification of the primeval geographical development of the Quaternary sediments, to the analysis of the aspects of these connected with the older geological formations, and to the establishment of their correlations. Especially as concerns the search for hydrocarbon-bearing structures, certain Hungarian and international experience in recent years has provided extensive proof of the value of the scientific information to be expected from such comparative investigations, and also its utilizability in the planning of the prognostic preliminary research and discovery work.

With regard to the above, it became our fundamental working hypothesis that the morphological facies types of the fluviatile and partly aeolian filled plain regions can in favourable cases be well parallelized by the Quaternary and Recent *geokinetic tendencies* of the areas, and by this means the classifying factors of the connections between the deep structure and the surface (previously treated as being of rather peripheral weight) in principle become interpretable in their causal correlations.

Even in the very first stage of the work of interpreting the region between the Danube and the Tisza, it emerged clearly that attempts can indeed be made to draw conclusions on the dynamic, and hence the deep-structural tendencies of the area from in particular the ordering conditions of the sediment facies of the regional details displaying *fluviatile and fluviolacustrine* filling. At the same time, the areas covered by aeolian accumulation caused some disappointment, for it was experienced that the research work was much more difficult, and almost impossible in this respect. The reason is that, together with other areal characteristics, the sheet thickness of the atmoclastic sediments and their regional development according to particle size are not governed by the processes of structural movement of the accumulation region during the sedimentation, or (even in the case of there being a connection) the genetic relations of such a nature prove practically impossible to evaluate. Unfortunately, in many areas of the region between the Danube and the Tisza aeolian sediments are involved, and these are such that the tectokinetic tendencies of the postsedimentation phase cannot be discerned from the conditions of their deposition. From this aspect the interpretation is of the most doubtful value especially in the northern part of the region, in the hilly district around Gödöllő to the north of the Fót-Üllő-Albertirsa-Cegléd line. In this district the developed configuration and the strong derasional, atectonic and sometimes soil-flow postsedimentation rearrangements resulting from the high relief energy values have further impaired the possibility of observing any tectodynamic tendencies, even compared to those of the plain terrains.

It is quite natural that the value of any deep-structural meaning derived from satellite information can be controlled only by comparison with deep-geological information acquired via the traditional geological and geophysical channels. This control work, however, is made appreciably more difficult by the circumstance that drillings penetrating to the substratum and which the correct stratigraphic documentation is available are limited mainly to only a few local centres in this area (larger town settlements and hydrocarbon-bearing districts, that have already been subjected to investigation), while at the same time (apart from the geophysical data network) we have no documentation concerning the deep structures of the extensive intermediate areas. Even the profiles of water-research borings and artesian wells sporadically sunk in the region between the Danube and the Tisza frequently display unreliable strata determinations, or in the majority of cases they do not penetrate to the desired depth.

The above reasons explain why even today there are considerable differences between the opinions and maps of the various authors, for example in the assessment of the relief conditions of the substratum in this region, or the regional characteristics of the geothermal gradient. With regard to the observed contradictions, it appeared reasonable to construct our own target maps in those places where there was a possibility to make modifications of theoretical importance by means of the provision of supplementary data.

In the parallel evaluation of satellite photographs and traditional working maps yielding geoscientific information, very substantial aspects for further research were provided by the study of false spectra in various variations. For the control of our consequences, the basic investigation material referred to is documented in black-and-white copies. This aim is served by the 22 working photographs to be found in the volume. For the same reason, however, the volume also contains reduced copies of the target maps that have been used to approach this purpose, some of them newly prepared.

It is well known that the photographs of areas not involving green vegetation are always the most interesting from the aspect of their geoscientific information content. Under our climatic conditions, therefore, the most useful observations are made in autumn, winter and early spring, when the disturbing factors are eliminated. The absence of cloud, and the ability of the remote sensor to penetrate readily through the atmospheric layers, are similarly primary conditions. Accordingly, from the available possibilities we present the investigation of photographic material obtained from LANDSAT-I in the autumn of 1973. It should be noted that photographs taken by LANDSAT and other satellites at other times are also available for purposes of interpretation, but because of the relatively slow development of the surface phenomena of value from a geoscientific aspect, it seems sufficient to analyze only a single series in order to attain a first approximation and interpretation of the groups of phenomena concerned.

The LANDSAT-I photographs examined do not span the whole of the region between the Danube and the Tisza simultaneously, but at the same time certain of these photographs also show the northern hills and other areas west of the Danube or east of the Tisza. In essence there are three series of pictures from the autumn of 1973 from which a complete montage of the region between the two rivers can be prepared. These photographs were taken by the satellite on 31 October and 18 November 1973.

The montage from October embraces the region between the sections of the Danube valley north of Harta and the sections of the Tisza valley north of Mindszent, including the ranges of the Cserhát, Börzsöny and Mátra Hills in the north. The southern tip of the photograph demarcated by the line Bócsa-Helvécia-Kiskunfélegyháza-Petőfiszállás-Baks is cloud-covered, and there are also some separate areas of cloud around Mikebuda, Tápiószöllős, Jánoshida, Jászladány and Jászapáti. The remainder of the region under investigation, however, is completely cloud-free and can be readily evaluated.

On 18 November 1973 the satellite recorded two series of photographs of the region between the Danube and the Tisza. One of these depicts the northern half of the region, and the other the southern half. Apart from a few insignificant areas of thin cloud above Budapest, Nagybaracska and Hercegszántó, they give an excellently evaluable clear reflection of the complete Hungarian part of the region between the Danube and the Tisza.

The evaluation is greatly facilitated by the fact that the series of photographs from 18 November overlap each other: the southern limit of the photograph of the northern half of the region is defined by a line joining the villages of Szakmár and Szatymaz, while the northern limit of the photograph of the southern half is a line between the villages of Dunapataj and Dóc.

The above facts virtually predestined the demarcation of the limits of the research area: the Danube valley in the west, the line Budapest-Gödöllő-Tura-Zagyva river-Szolnok in the north, the line of the Tisza in the east, and the Hungarian-Yugoslav frontier in the south.

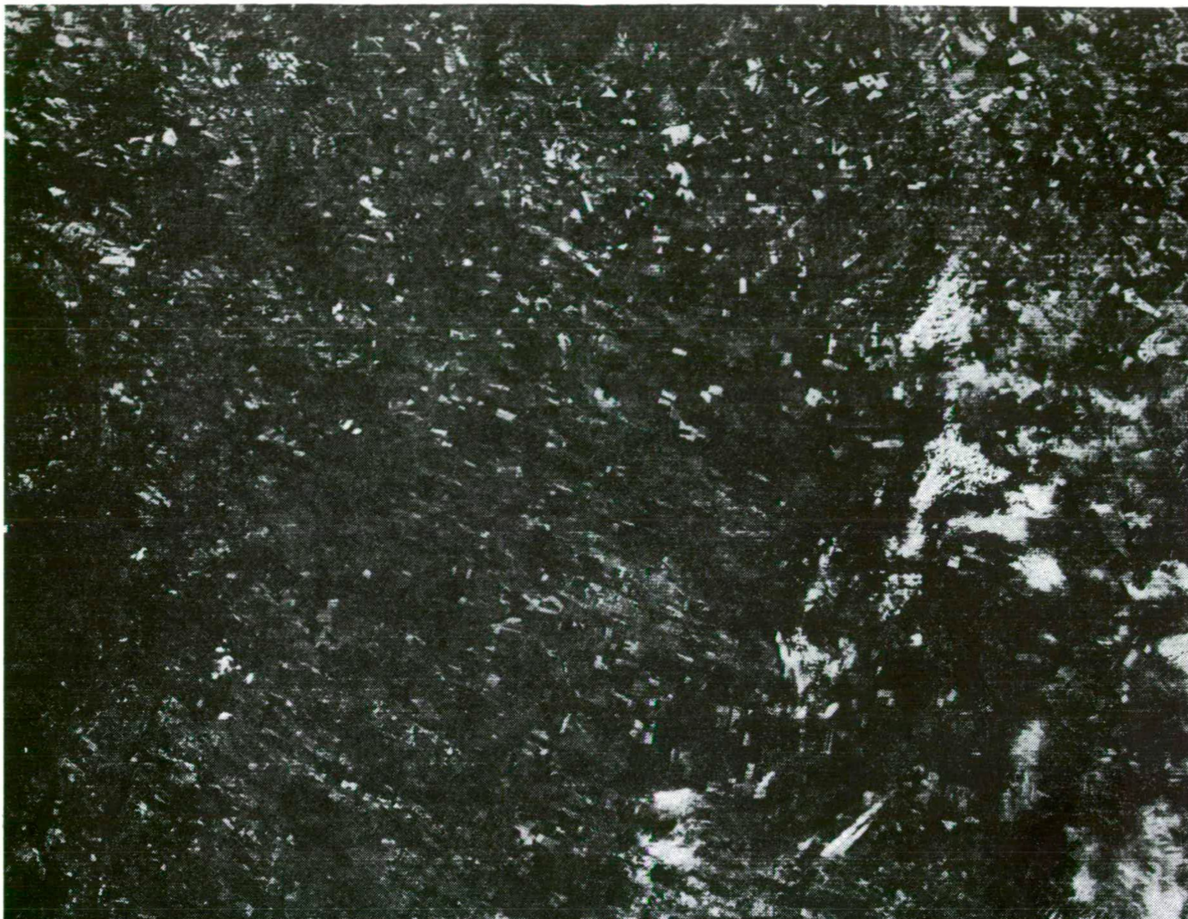
Naturally, we are fully aware that the region enclosed by these limits can only partially be regarded as a natural geographic regional unit. This question of demarcation is the most arbitrary on the northern edge of the region, for there the surface geological and geomorphological facies and structural units, but also those in the depths, continue without such a limit in roughly northerly directions. Nevertheless, this region had to be separated somewhere from the hill pediments and the plains of the fluviatile talus, and for convenience this limit was taken as the line of the Zagyva.

Ours are not the initial steps in taking such a decision. Although the morphogenetic characteristics of the Zagyva and Tisza alluvia lying to the north of the line between Abony and Szolnok conform very well with the topological features of the Tisza valley area to the south of Szolnok, certain authors (e.g. Láng) nevertheless differentiate this district from the region between the Danube and the Tisza, and mention it as part of the Central Tisza region. (Indeed, more recently LÁNG also classifies the hilly district of Gödöllő as a south-eastern projection of the Cserhát Hills that is covered with young formations.)

Of course, the wide alluvial valley plains of the Tisza and the Danube, which form the eastern and western boundaries, respectively, of the region in question, are not primeval geographical boundaries as regards the deep formations older than the Pleistocene: those surface relief energy and relief units and those Recent geological, petrological and morphological formations which promt us to draw the natural boundaries are not reflected in any way at all in the alignment of the substratum relief, in areal differences in the geothermal gradient, or even in the local orderings of the geomagnetic and the gravitational fields.

From the foregoing, that is from the geological and geographical openness of the area in every direction, it follows that the primeval geographic phenomena of the region between the Danube and the Tisza can not be explained fully only on the basis of investigations of the area involved, as the surface-forming processes in the area depend too on the effects of numerous factors outside the area. In the course of our work, therefore, we have taken into consideration the data on the neighbouring regions as well. A careful analysis was particularly necessary for the correlations arising from the directions of the main effects of the landscape-forming genetic processes. Thus, in the interest of the correct construction and realistic interpretation of the relevant maps, the control of borings for the study of deep stratigraphic data, for the acquisition of geothermal gradient values, for surface geological and morphogenetic analyses, for hydrogeographic analyses, and for the establishment of the compositions of the strata lying close below the surface (at depths of 0—50 m), was extended many kilometres beyond the boundaries of the region. Even in spite of this, in some cases difficulties arose in the drawing of parallels from maps taken from earlier publications, as in the meantime newer investigations by deep drilling, etc. had made it possible and necessary to revise these in part.

As regards the photographs taken in the individual spectral ranges, most information for our purposes is provided by three ranges of wavelength: 5000—6000 Å (range 4), 6000—7000 Å (range 5) and 8000—11000 Å (range 7). Range 4 (in the green spectrum) reveals the hydrologic characteristics, range 5 (red) mainly distinguishes the topographic features, the vegetation and the anthropogenic constructions, while range 7 (infrared) primarily makes possible the recording of thermal differences, demonstrating, for example, the different properties of uptake and emission of heat by the rocks of various natures, together with the petrographic specific heat characteristics, the incorporated and the high water-containing terrains.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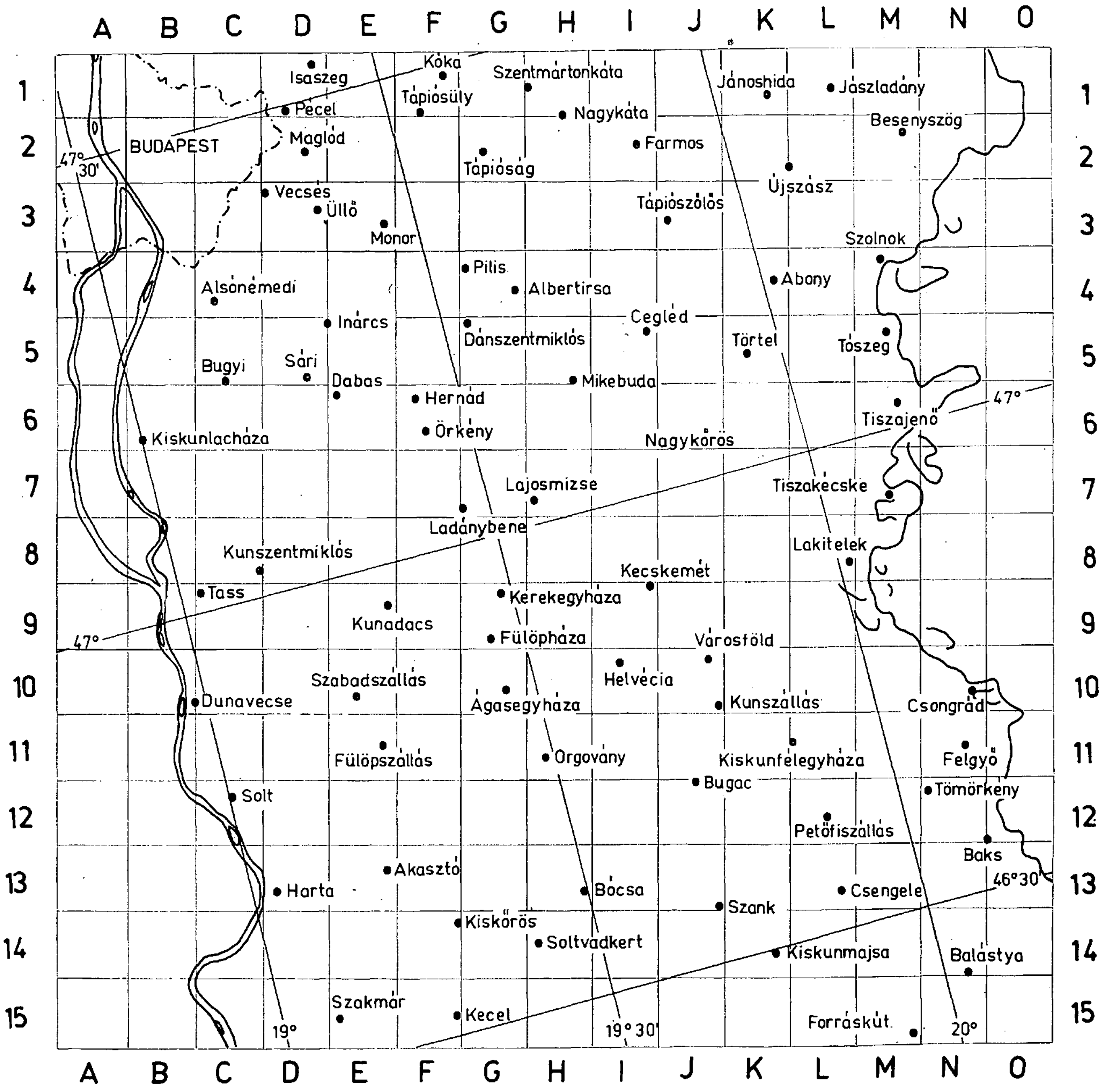
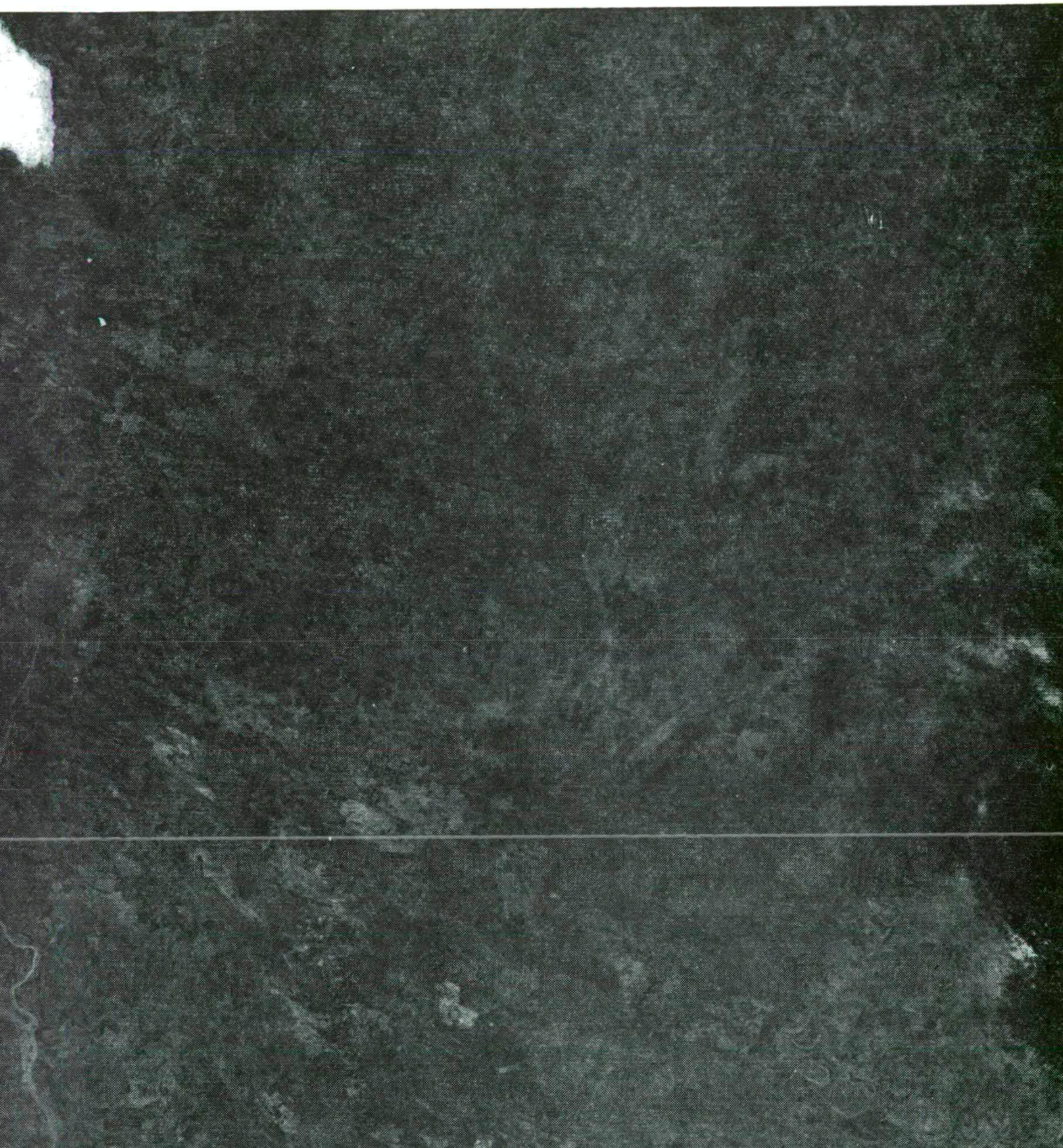


The interpretation net of satellite exposure derived from the northern part of the space between the Danube and Tisza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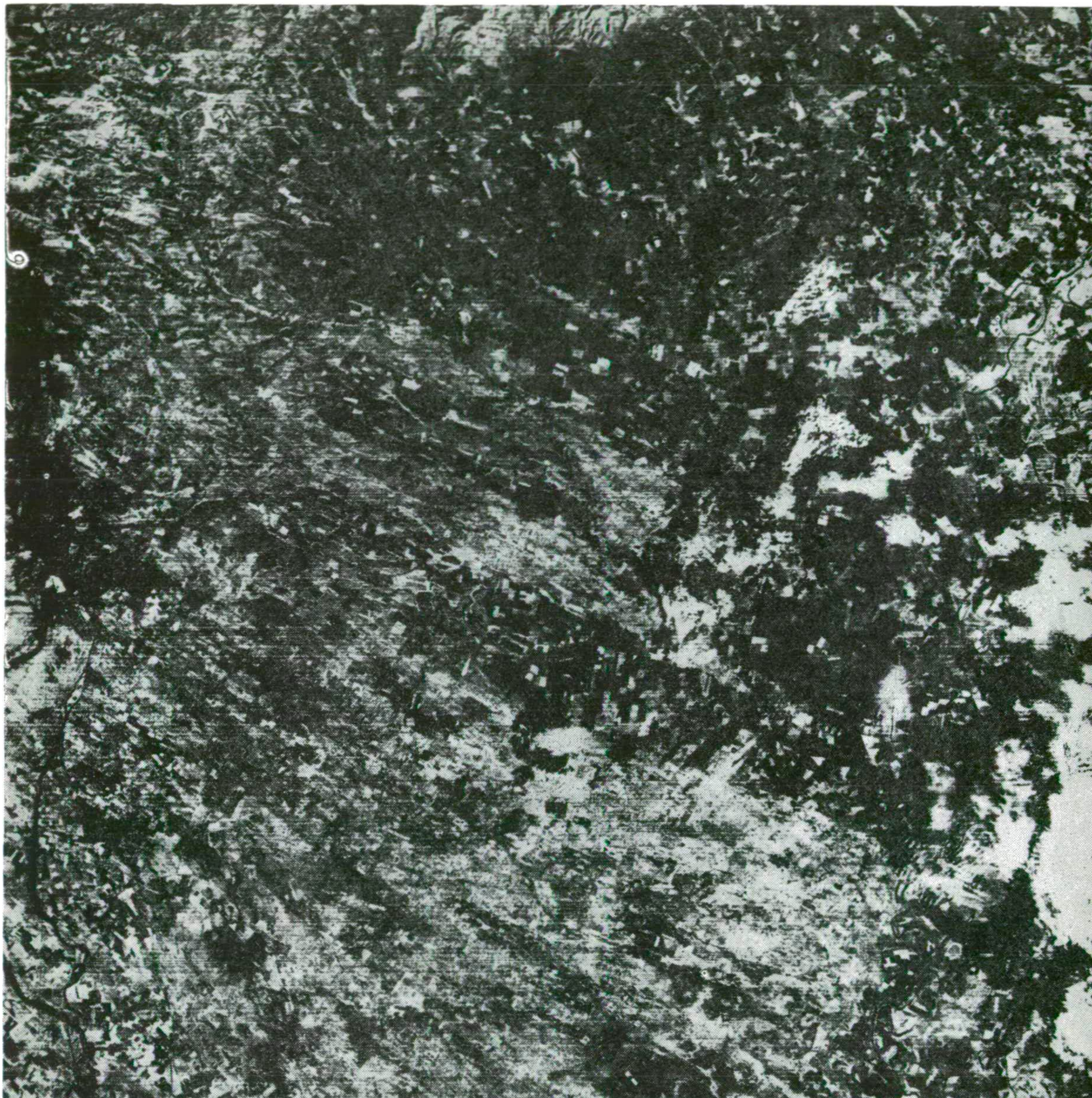
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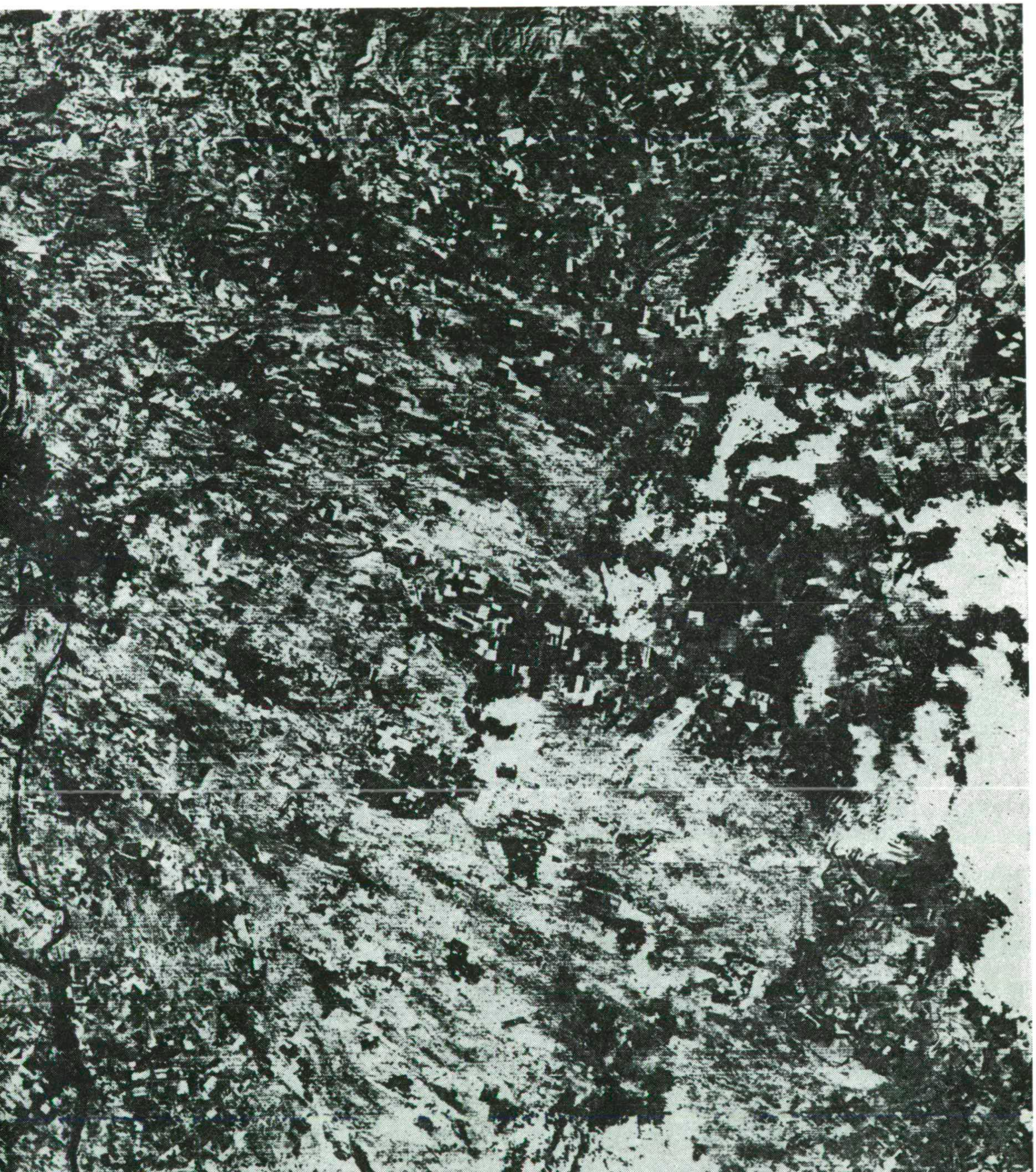
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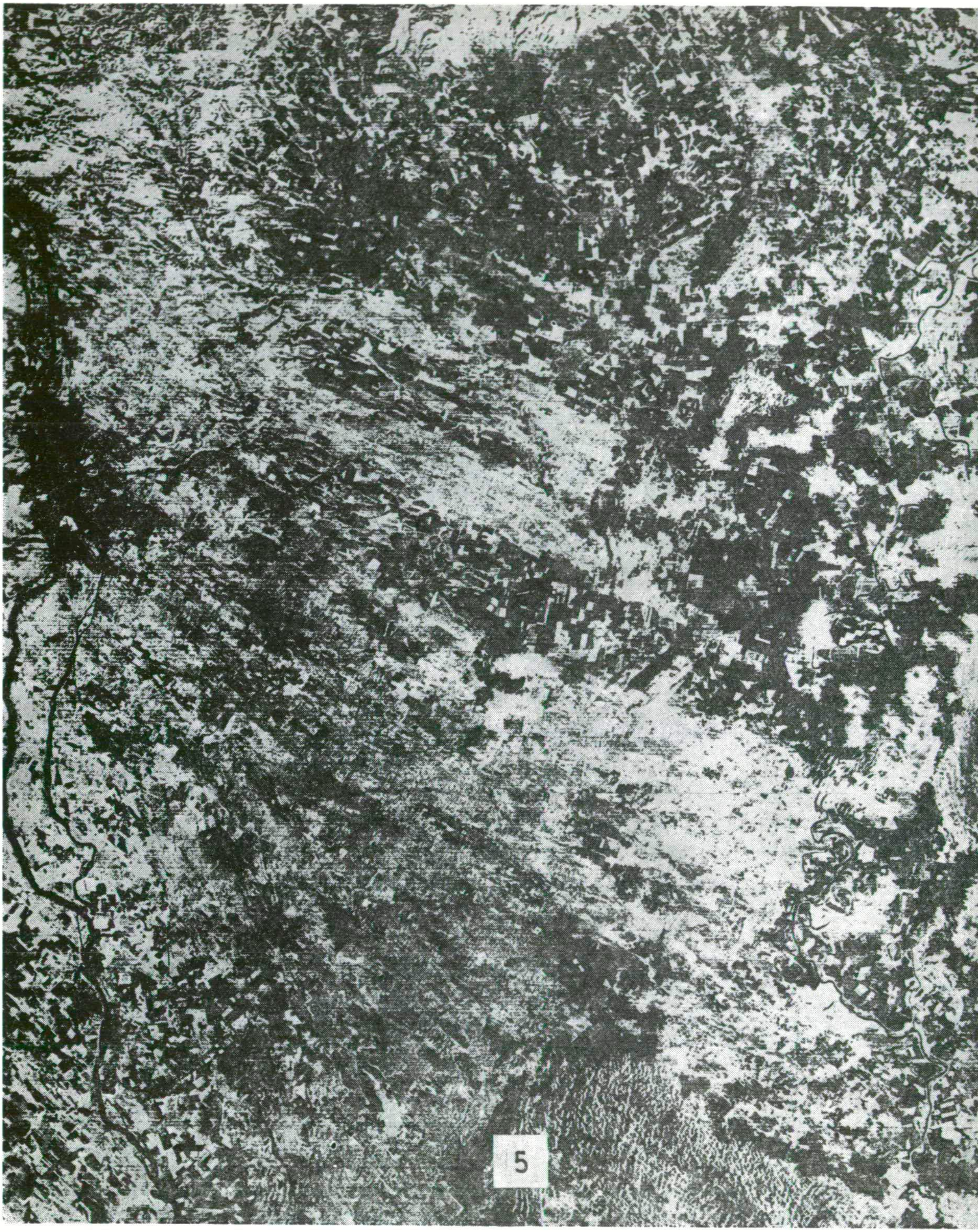
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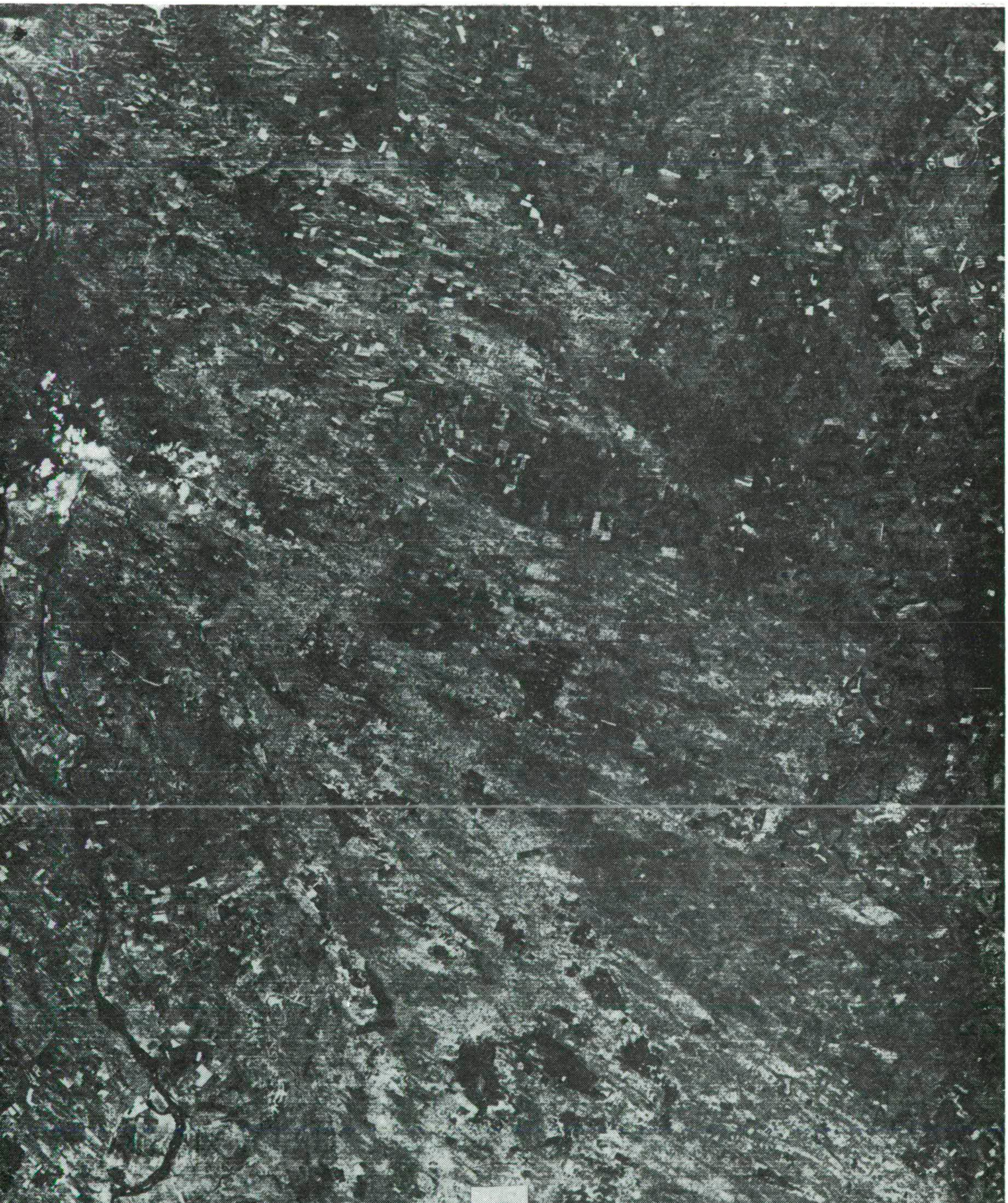
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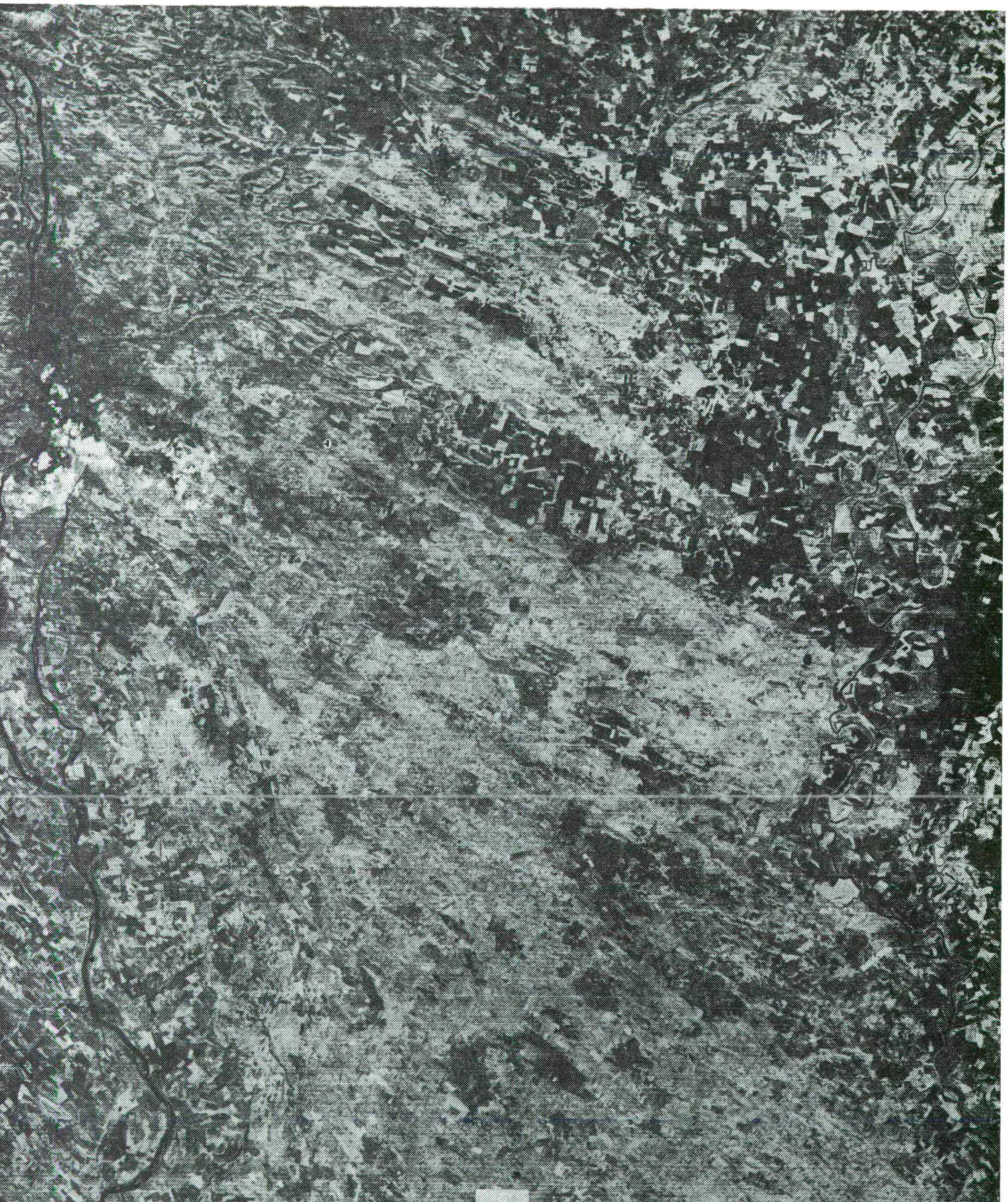
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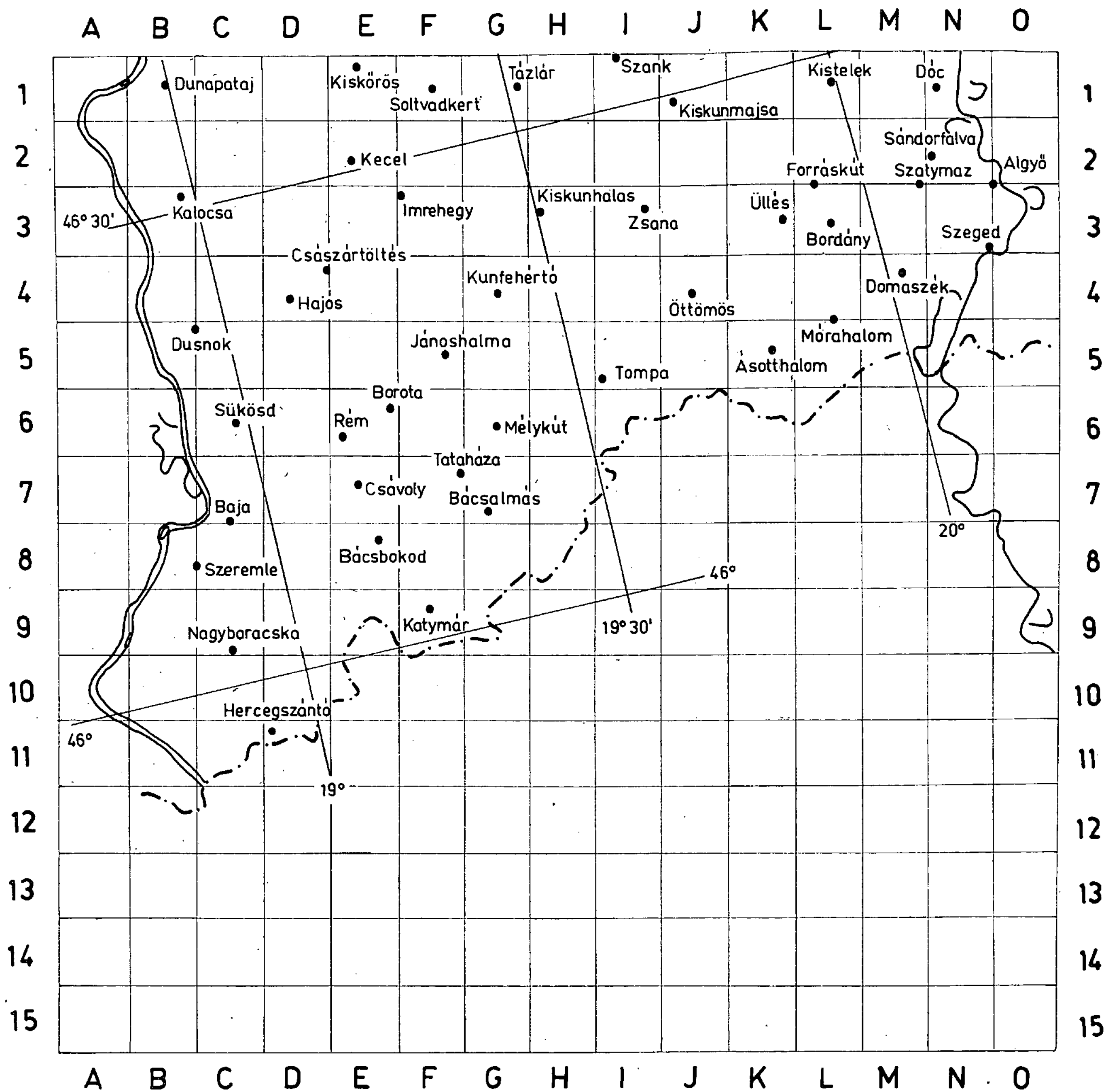
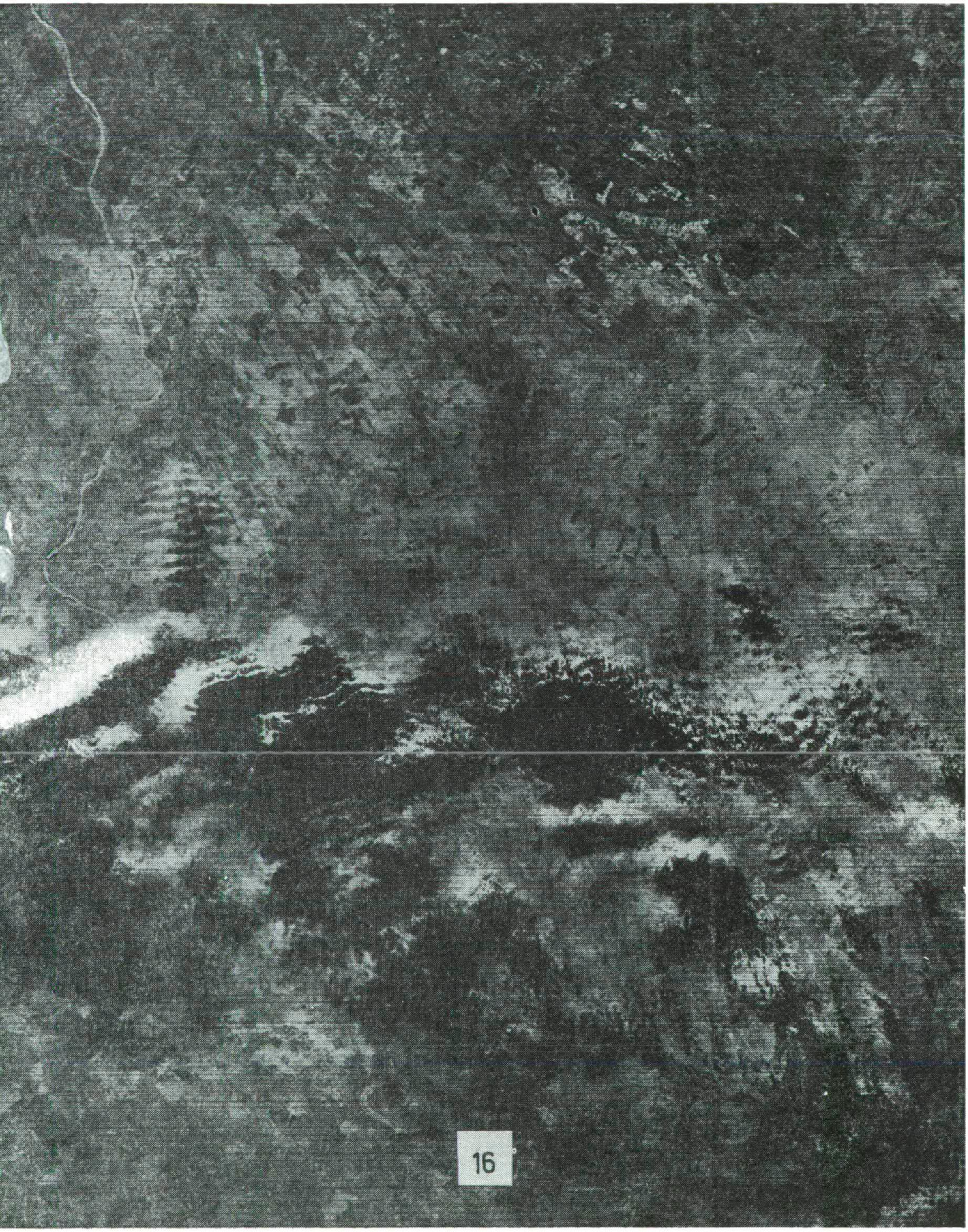


The interpretation net of satellite exposure derived from the southern part of the space between the Danube and Tisza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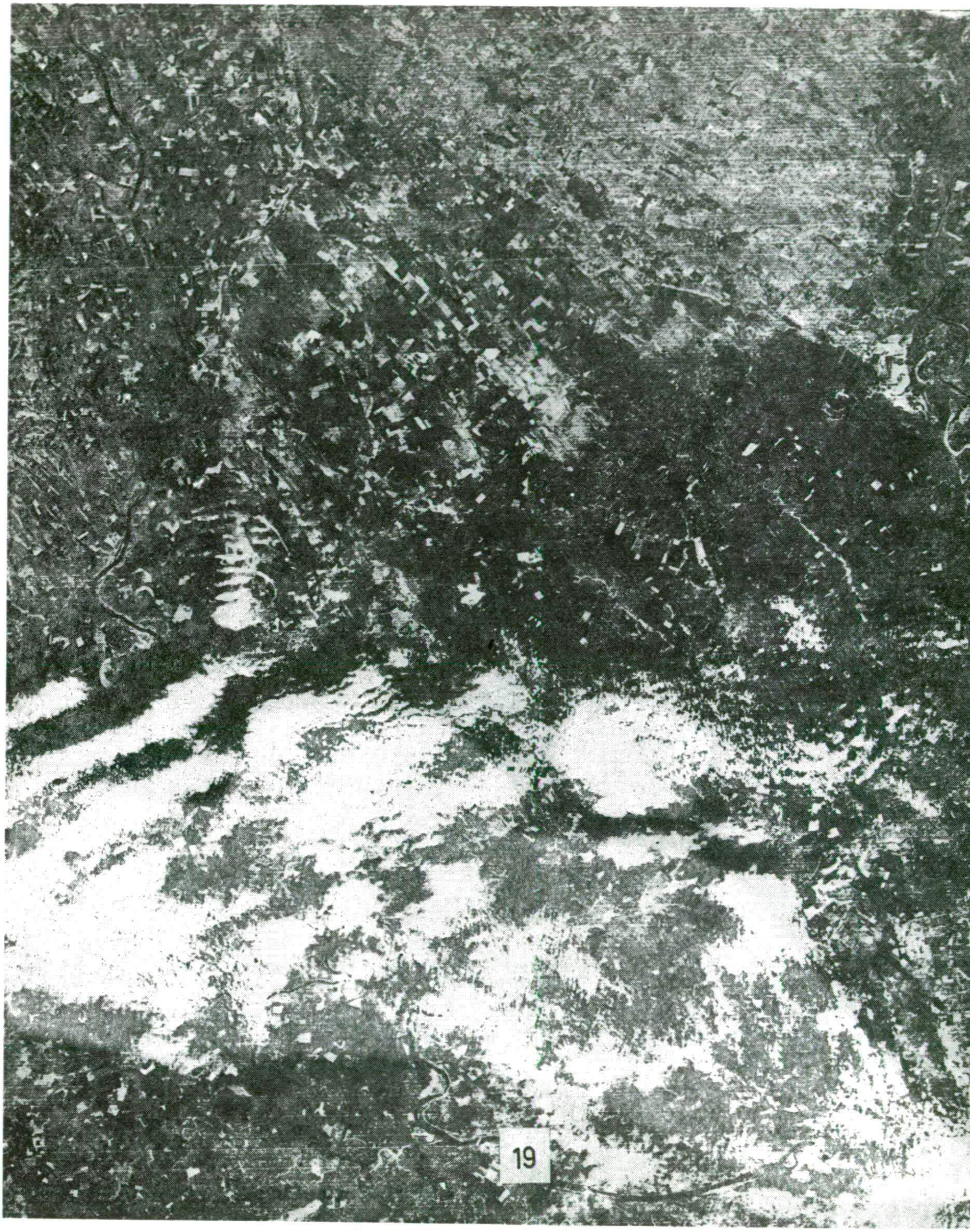
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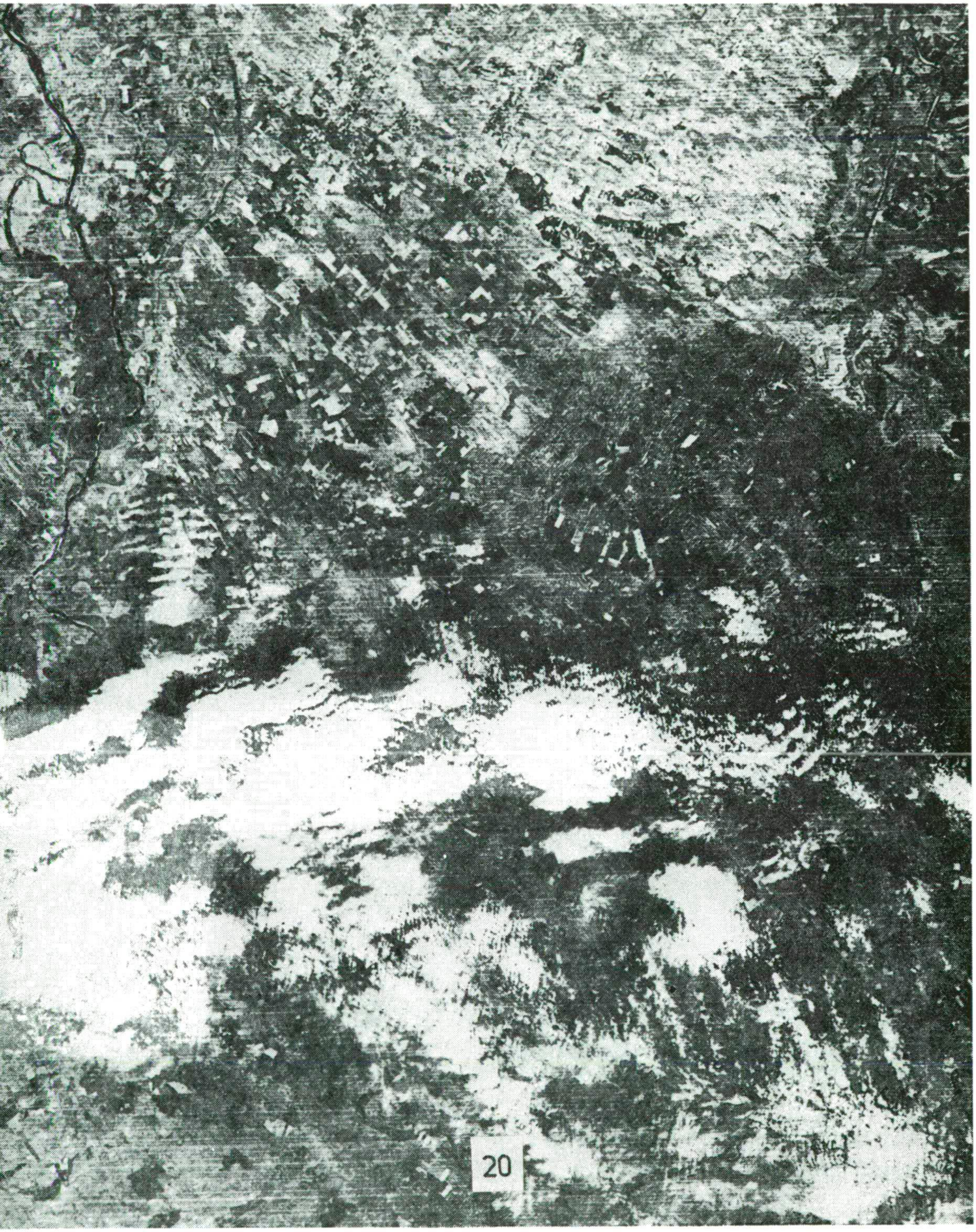


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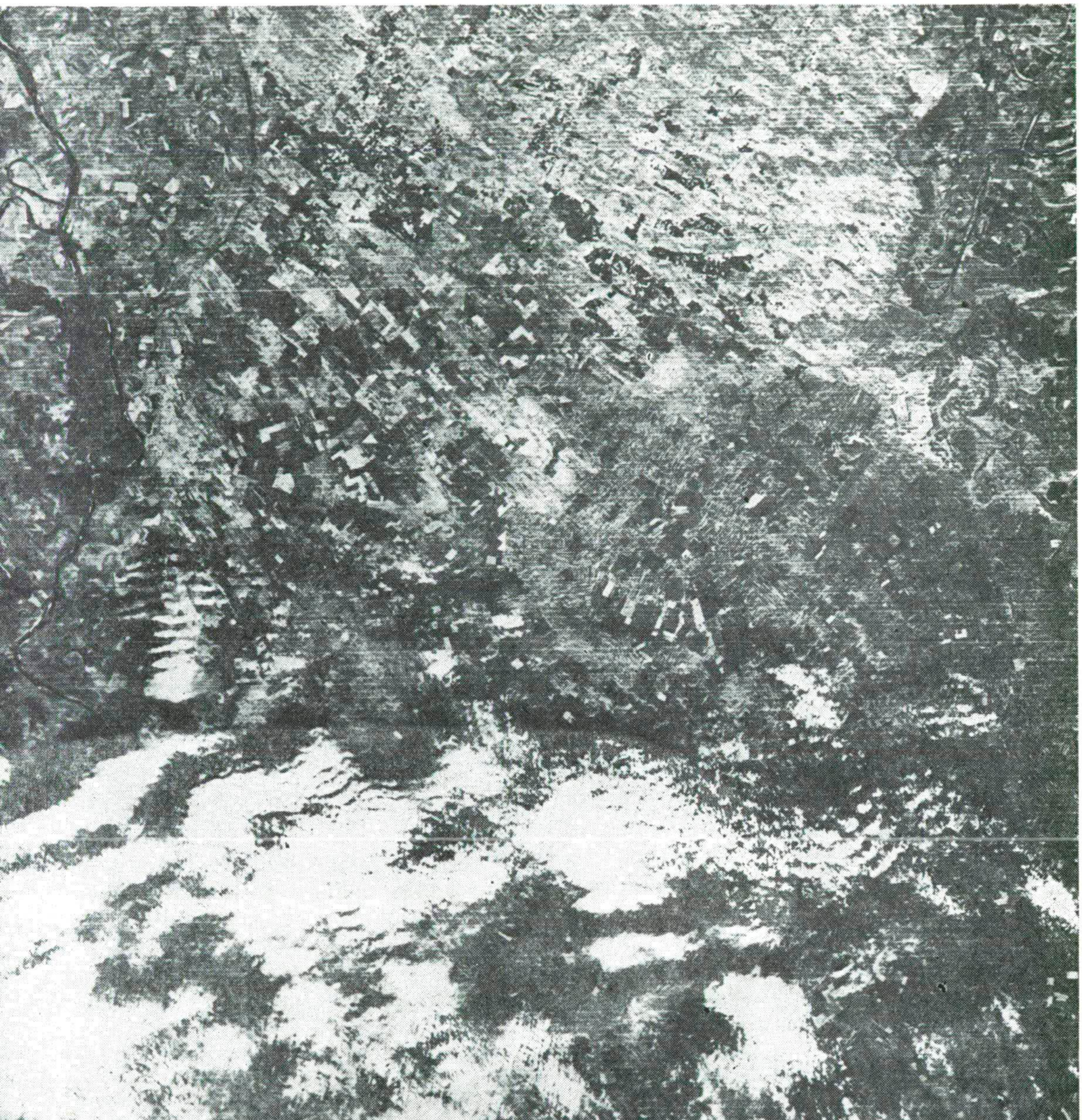


Unfortunately, both the original photographs and the montages prepared from them not only yield information on features of direct or indirect geoscientific natures, but also reflect phenomena which must be regarded as disturbing conditions. Instances of this are the differences in areal nature of the natural and agricultural plant cultures, or the existence side by side of plots of agriculturally employed soils displaying different conditions of cultivation. The spectrum combination most commonly used in interpretation practice is the false spectrum produced from the positive range 7, the negative range 7, and then the overlaid positive range 5. However, it was virtually impossible for us to utilize this combination, for the equidensity fields primarily expressed the spatiality of the partially already leafless woods, the grasslands, the vegetation-free ploughland and the unploughed stubble-fields.

In fact, therefore, in many cases we ourselves had to experiment with the various combinations, to find those most useful from a geoscientific aspect. We recommend a comparison of photographs 13 and 21 as an illustration; here the photographs in both cases date from 18 November (i.e. they are simultaneous), and the positive and negative series of information are coprojected. Nevertheless, photograph 13 is much more revealing geoscientifically than photograph 21. The reason for this is that photograph 13 was prepared not only by simple photointegration, but in addition by a picture-displacement technique of use for showing up the contour lines.

It should be noted that the geographical identification of the density fields and other observations on the satellite photographs is carried out with the aid of *interpretational auxiliary mesh grids* constructed for this purpose. The coverage area of the mesh grids employed was selected so that they should coincide with the edge-line of the pictures taken by the satellite, on the overlapping side of the photographs, and so that they should cover the research area as completely as possible. For these purposes, two 23.5×23.5 cm transparencies totally correspond for photographs on a scale of 1 in 500,000.

With the aim of ensuring the demands for exact fitting, the mesh grids contain the active bed plans of the Danube and the Tisza, (for the possibility of map transposition of the interpreted signal groups) a latitudinal and longitudinal grid system of the basic geographical coordinates of the region at 30-minute intervals, the more important settlements, and finally a 15×15 division ancillary grid, the letter and number coordinate indices of which permit the localization and identification of any detail in the region.

Appropriately sized outlines of the two interpretational mesh grids are enclosed.

We now present black-and-white copies of the original photographs employed and of their successfully utilized spectral combinations:

Group I: Photographic material on the northern half of the region between the Danube and the Tisza, taken on 31 October 1973

1 = positive spectrum of range 5
2 = negative spectrum of range 5
3 = positive spectrum of range 7
4 = integrated spectrum of positive range 5 and positive range 7
5 = integrated spectrum of negative range 5 and positive range 7
6 = integrated spectrum of positive range 7, negative range 7 and positive range 5

Group II: Photographic material on the northern half of the region between the Danube and the Tisza, taken on 18 November 1973

7 = positive spectrum of range 4
8 = positive spectrum of range 5
9 = negative spectrum of range 5
10 = positive spectrum of range 7
11 = negative spectrum of range 7
12 = integrated spectrum of positive range 4 and positive range 5
13 = integrated spectrum of positive range 7 and negative range 7, manipulated to demonstrate the contour lines
14 = integrated spectrum of positive range 4, positive range 5 and negative range 7

Group III: Photographic material on the southern half of the region between the Danube and the Tisza, taken on 18 November 1973

15 = positive spectrum of range 4
16 = negative spectrum of range 4
17 = positive spectrum of range 5
18 = negative spectrum of range 5
19 = positive spectrum of range 7
20 = integrated spectrum of positive range 4 and positive range 5
21 = integrated spectrum of positive range 7 and negative range 7
22 = integrated spectrum of positive range 4, positive range 5 and negative range 7

2. Appearance of the relief and relief energy characteristics of the region between the Danube and the Tisza in the photographic material obtained from LANDSAT-1

In the majority of cases satellite photographs provide no, or scarcely any, direct information on the nature of the relief in terrains displaying only a weak relief structure. Hovewer, the possibility of *indirect relief characteristics* is not excluded. Even plains exhibiting the lowest relief energy are not exceptions to this.

The most important indirect source of information on lowland areas is an *orientation* characteristic of the water network, which can not be traced back to the manifestation of the hydrodynamic laws determining bed development and bed changes on ideal plains. In addition to this, however, further information is given by the various abnormalities of the river section features; by the areal characteristics of the different soil and rock provinces: by the ground plan characteristics of the natural vegetation picture, and particularly of the patches of wooded areas; by the structural features of the agricultural plot areas; by the degrees of regularity of the surfaces with different moisture contents; by the prevalence of certain directions in the ablation; and by numerous other density-ordering factors not detailed here, which are manifested in varying manners and with varying roles from place to place; the mechanisms by which these latter factors are expressed have perhaps not yet been clarified exactly scientifically, but their existence and effects can be felt empirically in the different frequency regions.

On all of the spectral photographs prepared on the region between the Danube and the Tisza, but most markedly in the cases of nos. 2, 9, 11, 19 and 20, it can clearely be seen that the region can be divided into five areas which may be well differentiated on the basis of the relief:

(1) the hilly district of Gödöllő and the associated knolly district of Monor-Irsa;
(2) the very well-defined Danube valley plain (Central Danube Valley) extending from the Pest plain as far as the Yugoslav frontier;
(3) the plain of the Zagyva;
(4) the alluvial plain of the Tisza valley; and
(5) the centrally situated higher surface of the table-land of the region between the Danube and the Tisza, and the extensive eastern slopes of this.

This relief division is fully verified by the relief areas revealed by the study of the contour line maps, for the above five areas are also clearly demonstrated by our 5 m isohypsic maps of the region between the Danube and the Tisza (see Maps 1 and 2).

In connection with the relief maps presented, it should be noted that their construction was undertaken because the available large-scale topographic maps do not contain a detailed relief plan, and are therefore unsuitable for the study of the micro-relief. Although their contour line systems are sufficiently detailed, with the mass of their mosaic-information the sheets with scales of 1 in 25,000 and 1 in 10,000 make synoptic evaluation impossible.

Another reason why the 5 m isohypsae were required was that comparatively evened-out plains developed in extensive areas of the region between the Danube and the Tisza, and here 10 m hypsae are not sufficient for control of the phenomena groups of the slight relief differences still perceivable on satellite photographs.

Naturally, with a view to constructing uniform maps, the hilly areas with higher relief energies also had to be depicted with 5 m contours. This had the disadvantage that in these areas the contour network became so dense that they are inseparable in places in the reduced form suitable for publication. However, we feel that this circumstance too reflects the proportions of the characteristic differences in the relief types occurring in this region.

In accordance with the contour relief maps, the satellite photographs reveal that *the hilly district of Gödöllő and the associated knolly district of Monor-Irsa* is that part of the region which is situated highest above sea-level and which displays the most structured relief; it is separated by a sharp line from the table-land on the region between the Danube and the Tisza, from the Pest plain, and from the Danube valley in the wider sense, just as the morphologic boundary can be distinctly recognized towards the east too, in the direction of the Jászság.

The assumption that the knolly district is differentiated tectonically towards the Great Hungarian Plain is strongly supported by the circumstances that the knolly district is differentiated by an almost perfectly straight line along the direction Vecsés-Üllő-Albertirsa-Cegléd, and that the direction of this straight line coincides with the direction (NW-SE) of the main transversal fractures of the Hungarian Central Highlands. The tectonic preformation of the relief is even more strongly emphasized by the wide trench (with minor surface structure) (see photographs no. 10 between G/2 and K/4), which runs throughout the hilly district of Gödöllő and developed completely parallel to the previously indicated direction. The sides of this trench system are similarly indicative of parallel-running highland cross faults. This same tectonic direction is otherwise emphasized too by the valley of the River

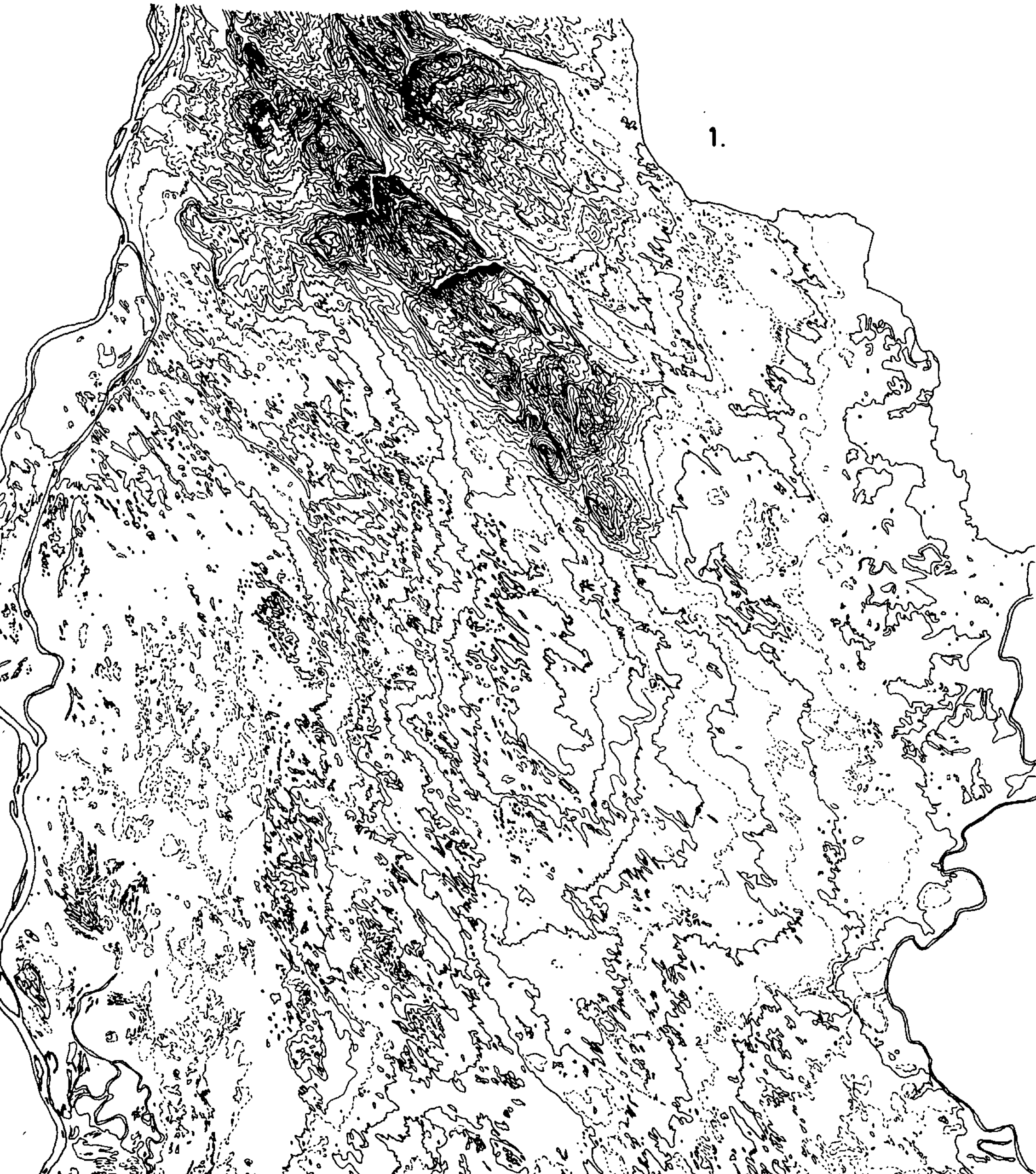


Fig. 1. Contour map of northern part of region between the Danube and the Tisza (JAKUCS—ANDÓ; JATE)

Galga, which forms the northern border of the main bulk of the hilly district of Gödöllő (this stands out sharply in photograph no. 13).

However, if the satellite pictures and relief map no. 1 are integrated with the relief map of the substratum (see map no. 29), these tectonic directions no longer stand out on this at all; indeed, just below the main bulk of the hilly district of Gödöllő a deep subsidence trough shows up. The longitudinal axis of this is perpendicular to the strike directions of the surface relief, i. e. in a NE-SW direction. From this circumstance it might be thought that *the strike directions of the present relief of the surface were not determined by the same structural movement tendencies which gave rise to the deep relief of the substratum.*

Two possibilities seem obvious as explanations of the above apparent contradiction:

1. The transverse local structuring of the surface relief was formed by quite young (Quaternary) tectonic "transform faults", the kinetic character of which differs from the vertical kinetic tendencies giving rise to the deep-buried relief of the substratum, and probably of older activity. That is, we are faced with a case of the directional discordance of tectonic phases following one another in time.

2. The NW—SE directions reflect the one-time flow directions of the connate water valleys (Primeval Danube) and delta branches that played a role in the filling-up and erosional shaping of the area.

Merely the interpretation of the relief conditions does not provide a sufficient footing for a final assessment of the above problem. We shall therefore deal in more detail later with this morphogenetic topic.

The *Pest plain* in effect belongs to the region of the Danube valley alluvial accumulation forming a young subsidence area taken in the wider sense. Its differentiation from the Central Danube valley is justified only because certain forms of the extensive, relatively high aeolian Danube ridges in the regions of Dunaharaszti-Ócsa-Bugyi and Sári ensure an isolation from the wider Central Danube valley plain extending to the south from Kiskunlacháza. This surface morphological differentiation is expressed most beautifully in the plot directions of photograph no. 3; north of the previously-mentioned boundary band, these mainly reflect a NW-SE directioning, while south of this band the directions of the main axes of the plots are irregular. It is interesting that the contour map is less well able to depict this régional-topological boundary.

The eastern boundary of the whole of the *Central Danube valley plain,* taken in the broader sense, is composed of a probably tectonically preformed, fault-free erosional valley rim, predominantly striking N-S, which can be well denoted by the line Sári-Dabas-Kunpeszér-Fülöpszállás-Akasztó-Császártöltés-Hajós-Baja-Herceg-szántó. This boundary shows up extremely well in the photographs (particularly in pictures nos. 3, 12 and 21), but it is to be observed especially sharply between Hajós and Baja, where differences in level of even 20—30 m have developed within quite small distances. Proceeding in the northerly and north-easterly directions from Hajós, this relief boundary is less well marked between the alluvial plain and the table-land of the region between the Danube and the Tisza; indeed, in some places it appears only in a flattened-out slope.

On the basis of the satellite photographs, and even the criteria of the relief map, this high relief energy terrain step between Hajós and Baja appears definitely to be an erosional terrain step; however, it can be taken as almost certain that it also shows

Fig. 2. Contour map of southern part of region between the Danube and the Tisza (JAKUCS—ANDÓ; JATE)

Quaternary tectonic preformation. This assumption receives stronger support from a comparison with the substratum relief, which is to be evaluated later.

The LANDSAT pictures allow the fluviatile-filled alluvial plain of the Central Danube valley to be classified as an almost perfect potamogenic plain, on the surface of which only the primeval fluviatile oxbow lakes cause minor relief differences. The entire Danube plain slopes extremely gently, but not completely uniformly, from north to south. The relief aspect of the plain is indicative of lower-section fluviatile activity (absence of oxbow lakes, forcing of wild arms to the edge of the plain) from the Csepel peninsula right down to Harta; south of this (from D/13), however, the characteristics of a central-section fluvial plain are evident.

Although the differences in the angles of the sloping of the surface are not revealed by the satellite pictures, these can be observed in the auxiliary contour maps. The average height of the surface above sea-level is 100 m around Kiskunlacháza, 97 m around Dömsöd-Tass, and 95 m around Dunavecse-Solt-Harta, for example. This means, therefore, that over a distance of about 55 km as the crow flies, the fall in the river level is only 5 m. On the alluvium to the south, however, which can be characterized by a central-section morphology, the sloping of the cathment area becomes somewhat steeper than this.

If the density of oxbow lakes on the Danube valley alluvial plain is examined in the satellite pictures, a further interesting regional characteristic may be observed, which is not reflected (or to only a slight extent) in the contour relief maps. This is the usually high meander density in the area of Baja. Particularly in squares B/6 and B/7, i.e. opposite Baja and on the right bank of the Danube a little to the north of it, a mass of generally inactive or filled-up oxbow lakes are to be seen; there is nothing comparable to this anywhere in the Central Danube valley. Naturally, the river meandered both to the south and to the north of this section, but it varied its bed in those sections much more rarely and much more slowly than in the area of Baja.

The explanation of the phenomenon may be that above Baja the width of the alluvial plain of the Danube valley narrowed to about one-third compared with the average value. Consequently, the erosional activity of the river strengthened in this area. More exactly: the erosional activity of the river overall did not become greater, but it was confined to a narrower areal band, and accordingly a higher number of erosional beds, dead beds, oxbow lakes, etc. were formed per unit area in unit time than in the widened-out river sections to the north and the south.

This genetic feature of the surface development naturally meant that primarily the erosional forms became predominant in the central Baja section of this constriction, whereas the flatter areas to the south and north of it were characterized by the accumulational, eluvial, catchment area overspilling forms. It is further obvious that these morphological differences are expressed not only in the aspect of the landscape, but also in the differences in the pedological and petrological facies, i.e. the erosional zone of the constriction will be characterized by a coarser-grained sandy sediment, and the wider alluvial areas by a predominance of finer-grained, more clayey sediments.

The *alluvial plain of the Tisza valley* accompanies the river in a comparatively narrow areal band on the right bank of the river; this is closely connected with a shift of the bed of the Tisza to the west in the course of the Holocene. The photographs (e.g. nos. 10 and 21) clearly demonstrate that (particularly south of the line

Jászkarajenő-Tiszakécske) the relief-determining role of the one-time Danube talus was manifested in the development of the surface almost completely up to the line of the Tisza, the latter river joining in with the forming and the filling-up of the landscape only recently. This phenomenon shows up so clearly in the satellite photographs that the genetic meaning of the relief is virtually indisputable. In squares MN/8 of photograph no. 10, it is unambiguous that Pleistocene sands originating from the Danube must be found near to the surface in the area of Tiszazug, even on the left bank of the Tisza.

Otherwise, the western edge of the Tisza Plain can everywhere be drawn quite clearly in the LANDSAT photographs, although the resulting boundary line is not such a sharp relief-separating boundary too as in the case of the eastern edge of the Danube valley. This is confirmed by the contour maps used as controls. In this case, therefore, the contact lines of the fields of different density primarily denote petrological boundaries, or the related pedological and hydrological boundaries. The question remains as to whether these facies changes played a role in slowing down the westward migration of the Tisza bed (e.g. on the sandy areas, in the sense of Lóczy's rule), or whether the present main directions of the Tisza express a conformation to the axes of the Recent geokinetic trenches.

As accentuated by a comparison with the isohypsic control maps, in the southern half of the Tisza plain the course of the 90 m contour line generally means the level to which the alluvial waters of the Tisza prior to the regulation may have reached, and beyond (or above) which the area is largely of aeolian origin. Although thin sheet-sand does also occur at levels below 90 m, our terrain investigations indicate that a series of clayey, muddy potamogenic sediments, with fluviatile or lacustrine development, can always be found at low depth on the alluvial plain of the Tisza.

We have seen that, under certain conditions, the relief information provided by the satellite pictures is substantially richer than of even the most detailed contour maps. This is understandable, as such maps can not express subsidences or upcavings of a relative nature with a magnitude possibly only of the order of some centimetres. By means of the indirect indications discussed above, however, the satellite pictures may possibly allow these features to be seen. As further support for our thesis, but in part with a view to approaching the main objects of our research, in the following we shall examine more closely from such a relation two of the minor details of the Tisza valley.

1. It can be seen well in photograph no. 10 that, in contrast with the previous main directions, the river changes its course to NW-SE between Tiszaújfalu and Csongrád; then, midway between the line joining Csongrád with Szentes it again assumes a south-southwesterly direction. At the same time, in this semicircular section (with the exception of the single oxbow lake below Csongrád) the river has ceased its right-bank meander formation. This group of symptoms resemble those arising if the river had been forced to avoid some obstacle in its path in this area; such an obvious obstacle might be a flattish eminence, for example.

If such an eminence really does exist, however, then its centre lies between the villages of Tömörkény and Felgyő, with a diameter (determined from the satellite photographs) of about 15 km.

The satellite photographs also readily reveal that this elliptically arrenged area is surrounded by the primeval Danube beds too, in part on the northern, and in part on the southern side. That is, this relative eminence in the terrain is not a young formation. Of course, it can not be said that this is a projection onto the surface of an effect of the movement tendencies of the substratum, since the maps of the Mesozoic-Paleozoic bed (see Maps nos. 27, 28, 29 and 30) depict a strong subsidence zone in this district; however, there must nevertheless be some cause for such an abnormality.

At any event, it is worthwhile to make a comparison with the Algyő detail of the satellite picture, where the already-known hydrocarbon-bearing eminence has similarly been enclosed by the Tisza to the east, while the formation of right-bank meanders has been stopped above the eminence (see squares NO/3 in photograph no. 21).

2. Another area of the Tisza deviating to the east and so far not satisfactorily interpreted falls slightly outside our research region, but it is nonetheless instructive. This is the section between the villages of Tiszasüly and Nagykörü (see squares NO/1,2 in photograph no. 11). Here too, the right-bank meanders are missing for some distance above and below Nagykörü, which indicates that the area encircled by the arc of the river was systematically avoided by the Tisza in the course of the history of its westerly bed migrations. It appears otherwise that this area too coincides with the relief trench of the substratum, but this in itself is not an excluding circumstance as regards the actual existence of a flattish eminence near the surface.

In connection with the relief characteristics of the *Zagyva plain*, the photographs instantly reveal that the rivers and streams running roughly in a southern direction off the water-catchments of the Central Highlands developed flattish-sloped, but extensive taluses on the northern edge of the Great Hungarian Plain; these rather confined the Zagyva and its right-hand tributaries to the northern edge of the hilly district of Gödöllő. The photographs of the Zagyva plain suggest, and the contour map confirms this, that the contour lines intersect the river, thereby substantiating the decisive role of the river in the filling-up process, and its active importance at present as well.

Finally, in an analysis of the relief features of the *table-land of the region between the Danube and the Tisza* it must be pointed out that the satellite pictures accentuate the table-land character most clearly in the northern and southern thirds of the region, though the relief (or geological) differentiation of the landscape from the Danube plain in the west and the Tisza plain in the east appears sharply everywhere. This may obviously be correlated primarily with the fact that there are enormous sandy deposits of the Pleistocene talus of the Danube on or near the surface on the northern part of the table-land, since this area was the central part of the large Danube talus, where the inactivated river valleys were even more underscored aeolically in the dry periods of the Pleistocene.

Both the satellite picture and our contour maps provide convincing evidence that the highest surface watershed divide line of the table-land is situated in the vicinity of the western edge of the area. The highest part of this divide line, however, is on the northern edge of the table-land. Proceeding eastwards and southwards from here, the surface displays a general, uniform slope. In all probability, this is connected in part with the smoothing-out of the talus, with the growing refinement of the sediments as regards grain size, and in part with the further subsidence of the subsidence areas of the Tisza valley, this process still being detectable even at present. The finer variety of surface forms sometimes showing up in the angular discordance too (e.g. the wide section extending in the direction of Helvécia-Szank from Örkény in photograph no. 2) may possibly indicate the aeolian rearrangement of the surface of the landscape in accordance with the predominating direction of the wind.

Another relief characteristic of the table-land is that the difference in level between the level of the Danube valley alluvium and the table-land surface increases considerably in the line Császártöltés-Hajós-Sükösd. A sign of this is that unusually high diluvial bank walls and steep slopes are to be observed along this line. With regard to this high terrain step, the problem may justifiably be raised that the sand material of the Illancs sand areas can have reached the site of its present aeolian accumulation from the direction of the Danube valley under the action of NW winds only if, at the time of this aeolian action, the Danube valley was not yet situated at such a deep level, and was not separated by such a steep loessy bank wall from the currently elevated Illancs area, as reflected by the present picture. The winds would scarcely have been able to transport the sand material over a 25—30 m high step and to deposit it on the high Illancs terrain. This argument too, therefore, strongly supports our earlier assumption that the high bank wall between Baja and Hajós was preformed tectonically in a young stage, and the erosion only emphasized this tectonic terrain step.

The fact that to the east, in the direction of the Tisza valley, the slope of the table-land increasingly flattens out, can clearly be attributed to two reasons in this section: (a) the progressively greater distance towards the east, which had a deciding influence on the grain size, the composition and especially the quantity of the aeolian deposits; (b) the permanent Tertiary and Quaternary subsidence of the eastern half of the area, and most markedly of the Tisza valley.

Our efforts to make the results of our interpretational work relating to the surface relief characteristics of the region between the Danube and the Tisza as realistic as possible prompted us to check the phenomena read off the satellite pictures not only via the contour line maps, but also by other means. To this end, we likewise evaluated detailed *relief energy maps* of the region between the Danube and the Tisza that had been constructed in our Department; reduced copies of these are to be seen in Maps 3 and 4.

Our relief energy maps were prepared with the use of the PÁRTSCH—KREBS method. The course of their construction was as follows. The 1 km^2 square network of the topographical maps with scales of 1:25,000 or 1:10,000 was taken as basis, and in each individual square a study was made of the height difference between the highest and the lowest feature point. This numerical value was expressed in metres, and referred to the centre point of the square. By means of interpolation, the points with the same values were joined together by isorelief energy lines, correspondig to the selected limiting values. The areal distribution of the relief energy values was depicted by shading.

Naturally, the characteristics of the relief of the area were taken into consideration both in the designation of the value categories, and in the choice of the size of the square network, the basic areal units. We therefore set out from the fact that our research area (with the exception of the hilly district in the north) is essentially a plain area, where the relief energy value is below 10 m over ca. 95% of the area. Accordingly, the slope conditions were depicted in relief energy differences of 2 m up to a limiting value of 10 m (i.e. 0, 2, 4, 6, 8 and 10 m). Up to 30 m, 5 and 10 m categories were employed (10, 15, 20 and 30 m), while in the hillier region the more appropriate 20 and 25 m intervals were used (30, 50, 75, 100 and 125 m)

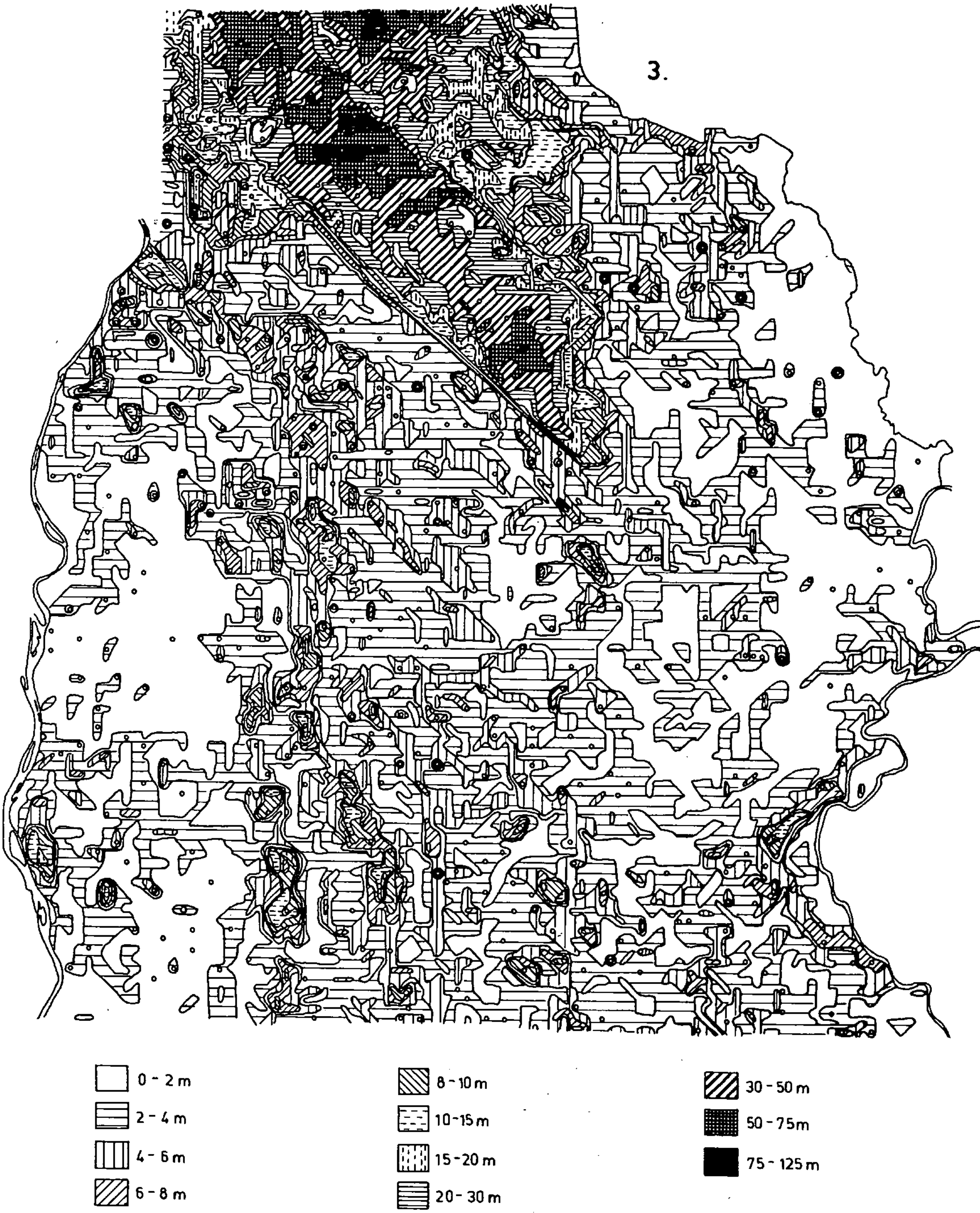


Fig. 3. Relief energy map of northern part of region between the Danube and the Tisza (FEHÉR; JATE)

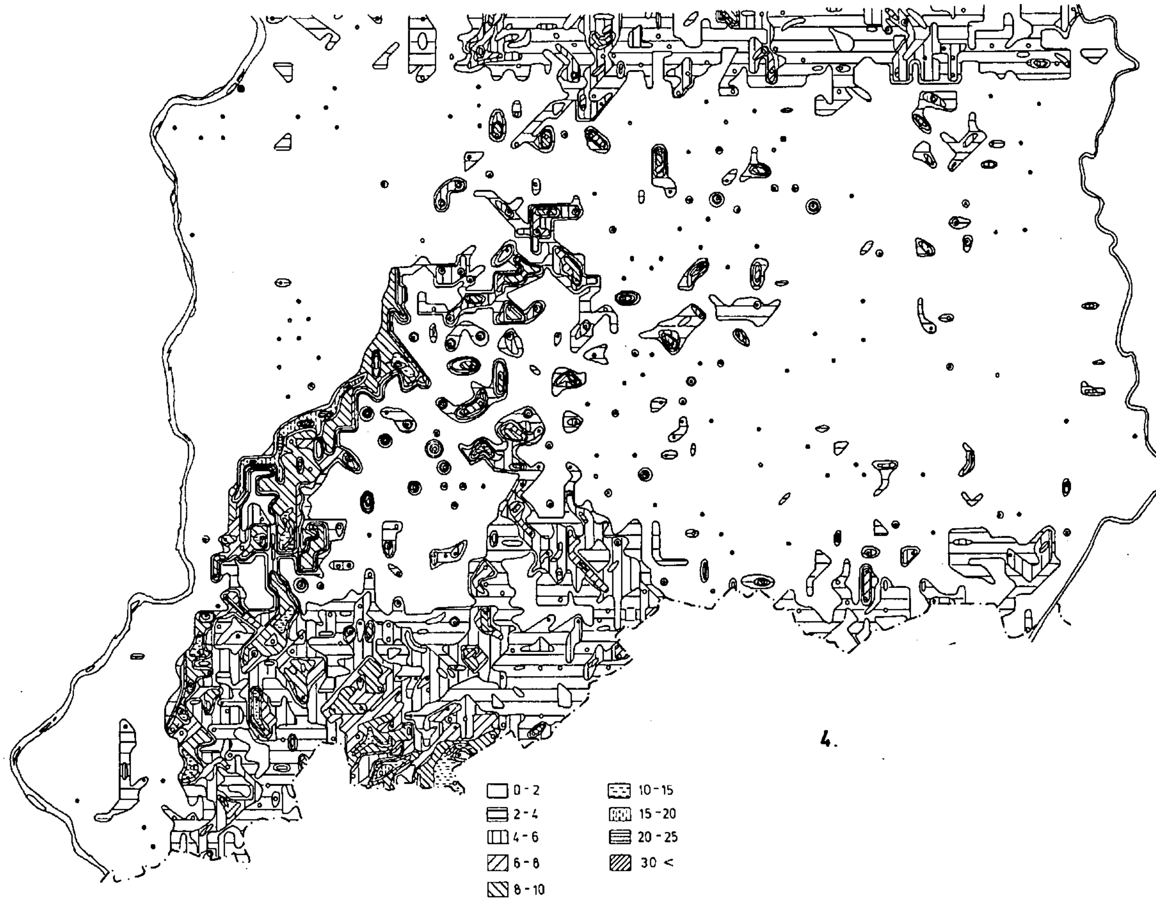


Fig. 4. Relief energy map of southern part of region between the Danube and the Tisza (FEHÉR; JATE)

As regards the size of the square network system we employed, it must be pointed out that this differed appreciably from that used by earlier authors, but this change was nevertheless justified. In 1924 KREBS, who developed the method of depicting the landscape in accordance with the relief energy, worked with a lattice network of 32 km². In contrast, in 1962 LÁNG constructed the first relief energy map of Hungary with a basic network of 88 km². The reason why we used the 1 km² areal network, which gives extremely dense information, was that we wished to prepare a relief energy map with a resolution which permitted the clear revelation of slight vertical structuring on these plain areas, thereby obtaining a faithful reflection of the structural morphologic differences.

The evidence of our maps supports in every respect the already-described relief information read off the satellite pictures. If Map 3 is examined, for instance, it is immediately obvious that, in the northern half of the region between the Danube and the Tisza, the lowest relief energy is displayed by the inundation areas of the rivers that developed by fluviatile accumulation. Their relief energy conditions are characterized by values less than 2 m; this is a virtually regular phenomenon elsewhere too on young potamogenic plains developing by perfect fluviatile planation.

This relief type can be broken down into two larger areas. One of these is the Solt plain, adjacent to the Danube; this is characterized by values of 0—2 m to the west of the line Bugyi-Kunpeszér-Szabadszállás right up to the Danube. Within this, in the area between Dunavecse-Szabadszállás-Fülöpszállás-Harta, and also in the districts of Kiskunlacháza and Dömsöd, values of 2—4 m appear in patches. Only two really high (15—20 m) centres are to be observed in the whole of the alluvial plain: the erosional island-hills of Solti-halom in the vicinity of Solt.

Similar relief types are found in the east, on the wide, flattish flood areas of the Zagyva and the Tisza. Towards the west, these are connected to the table-land of the region between the Danube and the Tisza by erosional rims. The inundation plain to the east of the line Jászberény-Törtel-Lakitelek can also be characterized by very low relief indices of 0—2 m, and only in the districts of Szolnok and Jászkarajenő are there small areas locally attaining values of 2—6 m.

The relief type with the greatest extent in the area depicted in Map 3 is the table-land of the region between the Danube and the Tisza, which can similarly be broken down into two parts with regard to its relief energy conditions: the areas to the east and to the west of the line Monor-Örkény-Kerekegyháza Kiskunfélegyháza. In the east the value of the relief energy is generally 2—4 m, and it attains or slightly exceeds 6 m only rarely, in small spots. The vast majority of the area is a surface rearranged by deflation, which becomes progressively lower towards the Tisza alluvium. In this district the relief energy map does not show up those fine (but morphogenetically significant) differences in relief mentioned earlier.

Areal patches of higher relief energy are observed on the western rim band of the table-land, but without exception these all occur in an isolated way and they therefore do not comprise a closed relief unit. Such areas are found in the district of Ócsa with a relief energy of 10—15 m, to the north-west and the south of Ágasegyháza, in the districts of Örkény-Tatárszentgyörgy, between Szabadszállás, Kerekegyháza and Jakabszállás, and in the vicinity of Izsák and Orgovány with relief energies of 15—20 m, and in some places even in excess of 20 m. These are all strongly structured, duny, drift-sand areas, regions of aeolian accumulation.

The area type with highest relief energy in Map 3 is the hilly district of Gödöllő, which on the basis of the relief indices is sharply differentiated from the districts with a plain character along the structural line Vecsés-Üllő-Pilis-Albertirsa-Cegléd. Its eastern boundary can be drawn along the line Cegléd-Tápióbicske-Tura, but this boundary does not coincide with the information from the LANDSAT photographs. The cause of this contradiction may be that the satellite pictures primarily give information on the genetic features of the landscape on a petrofaciological basis, and in this case there is a discrepancy in the relation of the relief conditions and the petrologic characteristics.

Within this regional unit, the highest relief energy is undoubtedly displayed by the knolly district of Monor-Irsa. About 80% of the area has a value above 30 m, and the maximum is attained in the region of Isaszeg-Pécel, with values of 75—125 m/km^2. Almost the same high values are to be observed in the knolly district between Fót, Gödöllő and Aszód.

The part of this knolly district with the lowest relief energy value is the area between Aszód, Gödöllő, Tápiószecső, Tóalmás and Tura. Towards the east, the relief energy progressively decreases from the 30—50 m characteristic of the western half, and along the line Tura Tóalmás-Nagykáta-Cegléd the knolly landscape is transitionally replaced by a zone with a relief energy of 2—4 m.

If a study is made of Map 4, which illustrates the relief energy conditions of the southern half of the region between the Danube and the Tisza, it is immediately apparent that the great majority (ca. 70%) of the entire region consists of plain areas where the value of the relief energy is less than 2 m/km^2. The map also provides striking and surprising evidence that the relief energy index is likewise below 2 m/km^2 over a considerable proportion of the table-land in the region between the Danube and the Tisza, just as on the potamogenically filled plains, i.e. in the alluvial districts of the Danube and the Tisza.

This terrain, with its very low degree of structuring, is in fairly strong contrast with the Bácska loess table in the south-western corner of the table-land; on this loess table, the relief energy indices generally vary between 4 and 10 m, but smaller localities in the area have values above 10 m, and spots with relief values of even 20—30 m are found.

From the aspect of the relief types, the third largest regional unit in Map 4 can be observed north of the line Kiskőrös-Pálmonostora, where the terrain generally has a relief energy similar to that on the Bácska loess table, in spite of the fact that the two areas differ significantly as regards their geologic-petrologic structures.

Finally, the fourth relief typological unit of the southern half of the region between the Danube and the Tisza is the area enclosed by the lines joining the villages of Kecel, Kiskunhalas, Kisszállás, Jánoshalma, Felsőszentiván, Csávoly and Kecel.

If these four regional typological districts are now compared with one another, it stands out as a characteristic difference that in both the northern and the southern bands of the table-land the basic character is given by areas with a relief energy of 2—4 m, smaller spots with higher relief energies emerging from this background. In contrast, in the central zone of the table-land certain high relief energy, but inextensive islands rise up virtually without the presence of transitional states from a very extensive area with the lowest relief energy (0—2 m).

This difference is probably in a causal correlation with the different morphogenetics of the districts: the central areal unit is a duny region displaying the most typical drift-sand accumulation, while primarily the deflative forms predominate on the loess table-land and the surface of the northern band. It is also probable, however, that, besides the factors already discussed, a role may have been played in the occurrence of these differences by the depth of the soilwater levels beneath the surface; this factor can exert a deciding influence with regard to whether the nature of the work of the wing is accumulation or deflation.

Both the satellite photographs and the relief energy map demonstrate that a line characterized by exceptionally high relief indices is the Baja-Császártöltés high bank, where the relief indices attain a maximum. On this line the most outstanding extremes are exhibited in the section between Sükösd and Hajós, and particularly in the region of Nemesnádudvar, where the relief values even exceed 30 m. Our interpretation is strengthened by all this: a combination of tectonic preformation and the bank-undermining activity of the Danube must be assumed in the development of this line.

3. Reflection of the Recent and Fossil Age hydrological and hydrogeological characteristics of the region between the Danube and the Tisza in the photographic material of LANDSAT-I

The LANDSAT-I photographs of the region between the Danube and the Tisza provide excellent information on the Recent hydrography of the region, but also in many respects on the natural water network prior to the regulations; indeed, in certain areas they even permit an orientation as regards the otherwise unobservable traces and hydrological connections of long dead and abandoned water systems. That this is indeed so was truly demonstrated when we prepared the present natural water-network maps of the region (see Maps 5 and 6) and compared these with the satellite photographs. It turned out that the latter photographs reflect occasional water catchment valleys connected to the water courses, the dried-up floodwater river beds, and even the no longer used old bed directions, which do not show up in even the most detailed hydrologic maps.

Of course, in the period prior to the regulations of the rivers the picture of the hydrologic network was different from the present one. There were huge areas of bogs, swamps, and periodically waterinundated land, while in places the rivers were accompained by wild arms and floodwater beds. Some information on these is provided by the oldest maps, for instance the hand drawn map-sheets of the first military surveys at the time of Josef II, since these were prepared before the river regulations and flood prevention work at the end of the 18th century. However, under the then prevailing conditions, accurate mapping of the soil level in these districts of bogs and marshland, which were often difficult to traverse, and often involved point-identifying measurements and resections (and even distance estimations) only from boats, was not always possible. At any event, in the interest of being able to control our coception of the primeval hydrographic state based on the evaluation of the LANDSAT pictures, and partly so that the satellite information itself should become controllable, we primarily extracted from these early military maps the information relating to the old water network, and from this constructed the primeval hydrographic maps of the northern and the southern halves of the region between the Danube and the Tisza (see Maps 7 and 8).

Accurate and detailed information on the groundwater states and the depth

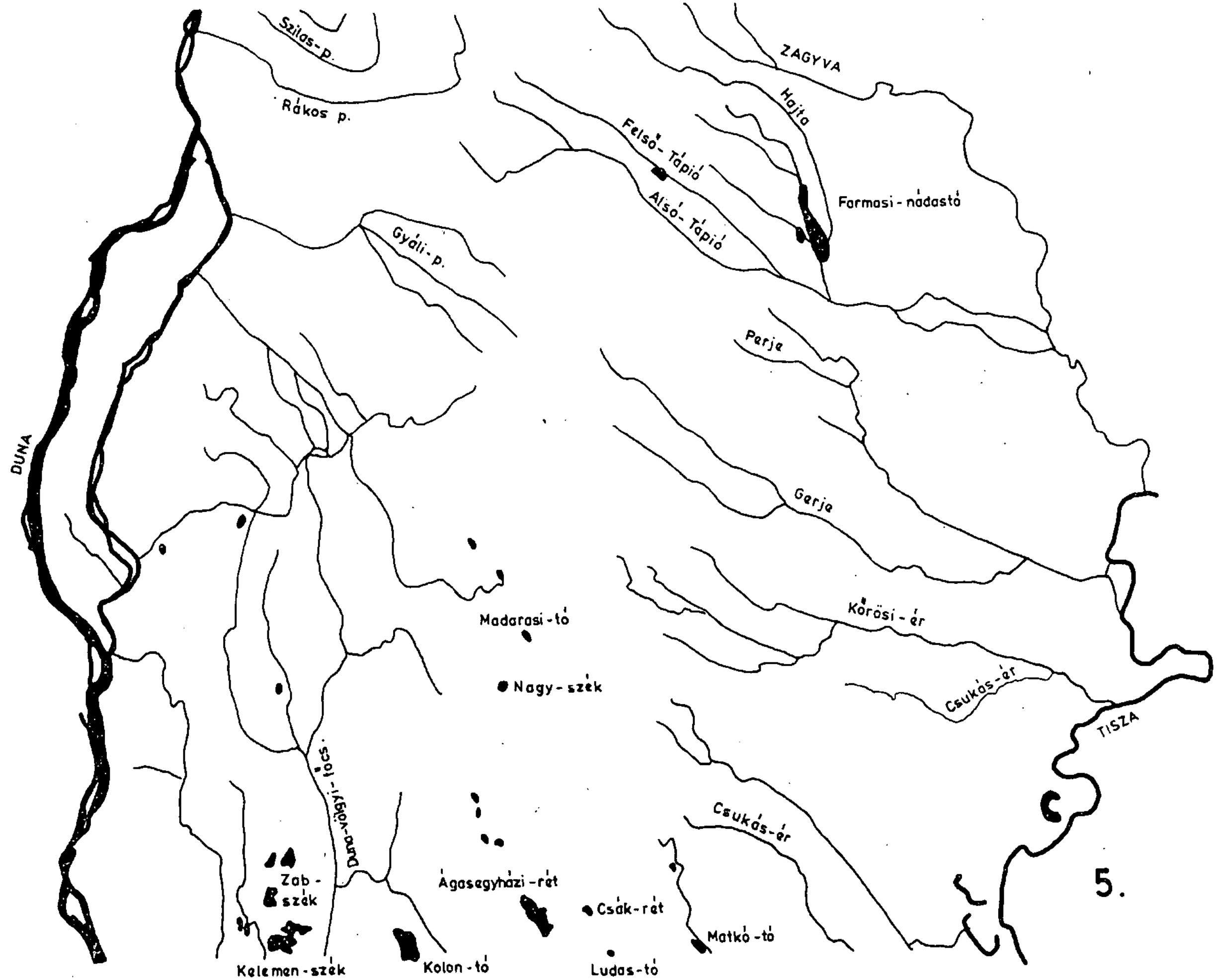


Fig. 5. Contemporary natural hydrogram of northern part of region between the Danube and the Tisza (OVH)

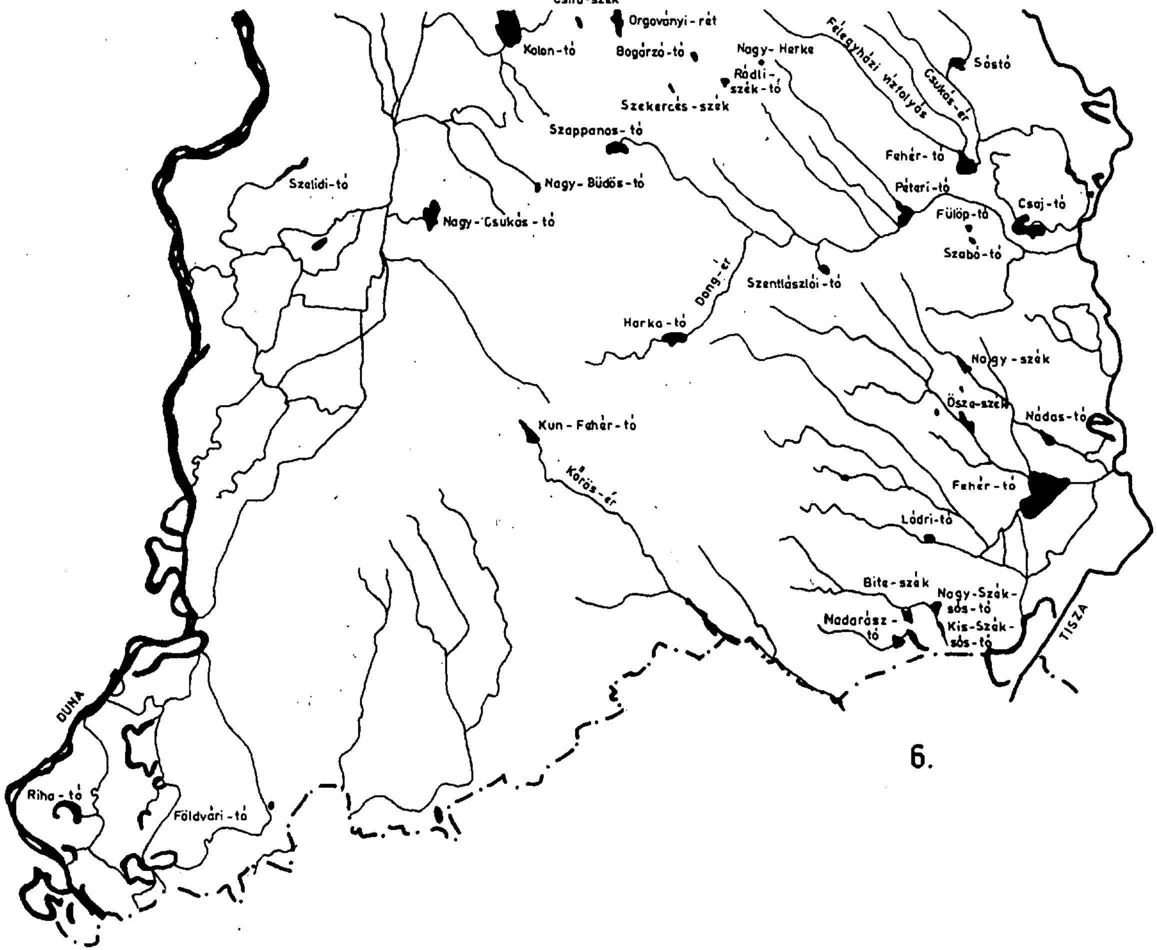


Fig. 6. Contemporary natural hydrogram of southern part of region between the Danube and the Tisza (OVH)

of the groundwater below the surface in the region between the Danube and the Tisza is provided by the groundwater level maps of RÓNAI and BOCZÁN (1961), which were similarly used in the evaluation of the satellite photographs (see Maps 9 and 10). These unambiguously prove that, over the greater part of the region between the Danube and the Tisza (both on the table-land and on the alluvial plains), the level of the groundwater is 0—3 m, i.e. it is at a very small depth. Characteristic deviations from this are observed merely in the hilly district of Gödöllő, on the Bácska loess table-land, and on the flood plains near the beds of the Danube and the Tisza. For these latter the average groundwater depth is 3—6 m.

With the aid of the satellite photographs, we attempted to decide the extents to which the correlation in question may be caused by the subsoil water level depression conforming to the river beds, or by the thicker (higher-surfaced) Holocene sediment accumulation of the flood plain zones near the beds. It appears that both factors play a role, and that their effects can be evaluated only in a complex way, their proportions varying from place to place.

In good conformity with the hydrologic maps, the photographs of the *northern part* of the region between the Danube and the Tisza (primarily nos. 8, 9, 10, 11 and 13) permit the differentiation of the following five large hydrogeographic units:

1. The hilly district of Gödöllő and the knolly district of Monor-Irsa, where there is a predominance of narrow, but deep valleys of streams and torrent water courses, primarily exhibiting a tendency to incise, and with a comparatively high fall. In this area there are neither wide, filled-up alluvial valley plains, nor lakes and other standing water. The stream beds, with a NW-SE axis, generally follow the trench-like, long, but narrow intercolline basins which are indicative of the erosional phases of the one-time Danube valleys (and possibly the transverse subsidences preforming these). Overall, the hydrographic picture points to a typical young elevation.

2. The broad potamogenic plain of the Central Danube valley follows the left bank of the present bed of the Danube in a width of about 15—20 km to the south of the line Kiskunlacháza-Bugyi. Its surface clearly reveals the oxbow traces and characteristic muddy bank bands of the dense changes in the bed of the river in the Holocene. It can also be observed extremely well that, in the north, the sand dune terrain separating this area from the Pest plain is an aeolian cover sheet even younger than the fluvial eluvium, since in the line Kiskunlacháza-Bugyi the oxbow lakes run out from beneath this sheet and begin blindly, i.e. their northern section is missing.

Another interesting characteristic of the Danube valley plain is that a large number of swamps of a constant nature developed on it earlier, but the great majority of these (even in spite of the evidence of the primeval hydrographic map 7) were localized to the eastern strip of the wide inundation area, while on the western half of the valley plain, lying closer to the Danube, only oxbow remnants with a linear course can be observed. From this circumstance it can be adjudged that the Recent fluvial accumulation caused sedimentation to a higher level on the bed-side band of the valley plain than on the edges. It may also be considered, however, that the eastern rimline of the potamogenic plain is preformed with an active breakline (currently too) resulting in a certain terrain subsidence.

3. The hydrologic picture of the table-land of the region between the Danube and the Tisza is characterized mainly by the absence of a natural network of running streams, and in addition by a series of constantly or periodically filled lakes isolated from one another in small deflation depressions. The axes of the latter indicate the

Fig. 7. Connate hydrogram of northern part of region between the Danube and the Tisza (JAKUCS—ANDÓ—FEHÉR; JATE)

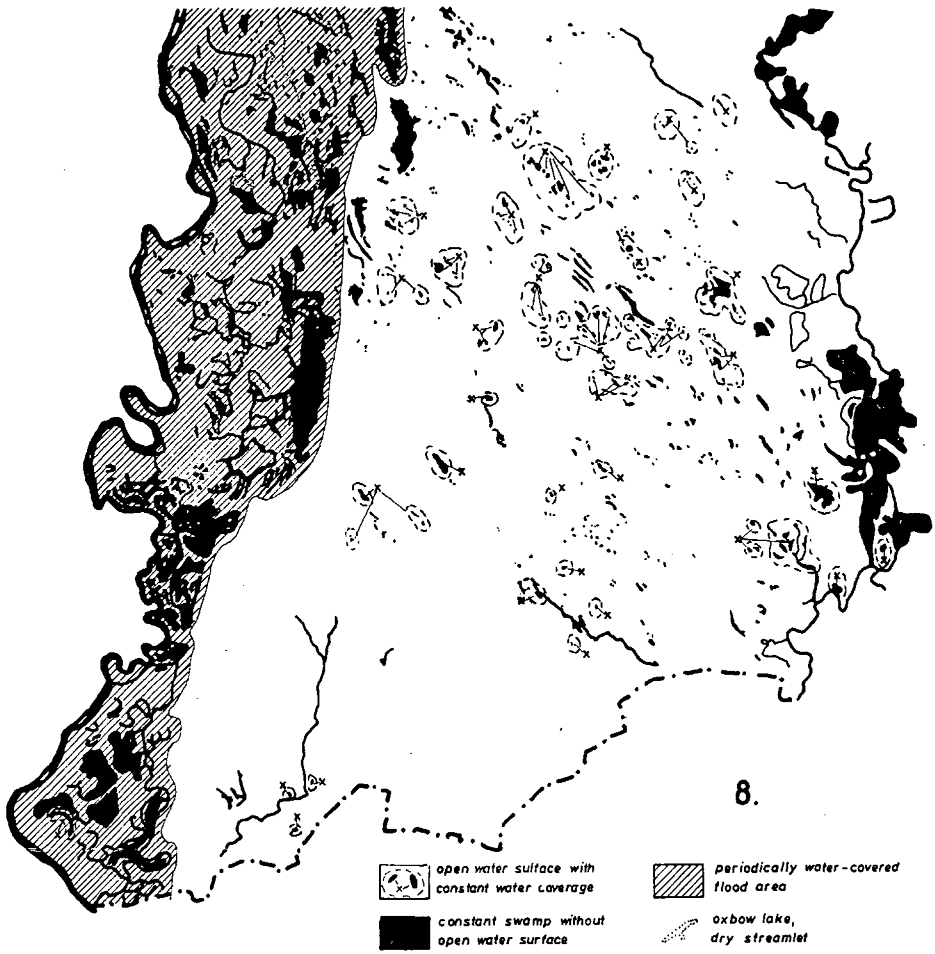


Fig. 8. Connate hydrogram of southern part of region between the Danube and the Tisza (JAKUCS—ANDÓ—FEHÉR; JATE)

predominant wind direction in the southern half of the area, whereas in the northern half they mainly show the one-time primeval Danube valleys and the directions in which these were filled up.

The satellite photographs especially well illustrate the filling-up directions of the Pleistocene primeval Danube along the line Monor-Pilis-Cegléd. At the same time, the primeval hydrographic map reveals that a flood area periodically covered with water should be seen in the district enclosed by the lines Tápiószentmárton-Abony-Szolnok-Vezseny-Cegléd-Tápiószentmárton, the water-network features of this area having been determined similarly by the one-time flow-off directions.

4. The section of the Tisza valley extending to the south of Szolnok is followed on the right-hand bank only by a quite narrow one-time swamp zone, which is a

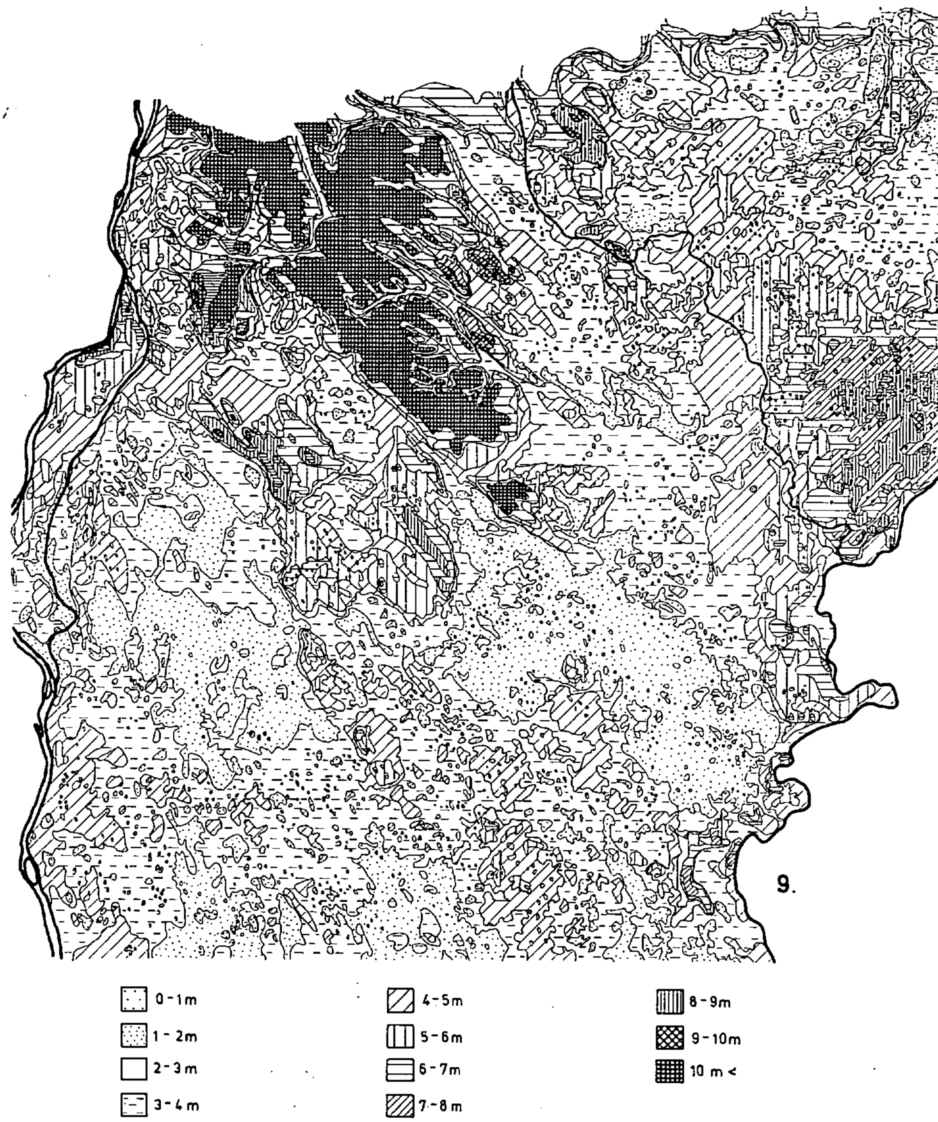


Fig. 9. Groundwater surface depth map of northern part of region between the Danube and the Tisza (RÓNAI—BOCZÁN)

different feature in contrast with the Danube valley. In places there were no swamps and bogs on the right-hand bank, but the western boundaries of the occasionally very narrow alluvium band must be regarded as valley rims of a central section nature, shaped out by lateral erosion. The essence of the explanation of the phenomenon is correlated with the permanent westward shift of the river in the Quaternary.

5. The hydrologic characteristics of the Zagyva plain were determined by the areal determinants of the accumulation processes. The rivers operating here, which sedimented out huge amounts of alluvium in both the Pleistocene and the Holocene; constantly strived to approach the central axis of the subsidence area of the Jászság, and thus also accumulated the central masses of their talus there. By this means, they constrained the swamp zone to assume a rim position. Accordingly, the development of the swamp series to the north of Tápiószele, which still existed at the time of *Josef II*, can only be brought into correlation to a minor extent with the Pleistocene bed-entrenchments of the rivers performing the filling-up (mainly the Zagyva, Tarna and Tápió); a reflection is much rather given of the shifting-away of the beds of the right-hand subsequent water courses striving towards these rivers. Similar bed shifts and the accompanying groundwater swellings are otherwise characteristic along almost every rim talus on the Hungarian Plain, and elsewhere too are indicative of the morphogenetics described above.

From a complex comparison of the satellite pictures, the drawing of the recent water network and the hydrological conditions prior to the regulations, it appears that in the northern half of the region between the Danube and the Tisza there are five small districts which even today are to be evaluated as appreciably subsiding part-basins:

1. The Pest plain.
2. The Central Danube valley, and particularly its eastern rim areas.
3. The Zagyva basin between Jászberény and Újszász.
4. The region of Cegléd-Abony-Szolnok.
5. The district of Alpár, indicated mainly by a large westerly widening-out of the Tisza.

It is worthwhile observing that all these hydrogeographic subsidence areas coincide almost exactly with the geokinetic data on the northern part of the region between the Danube and the Tisza (see Map 37); indeed, with the exception of the Central Danube valley plain, they are also confirmed from the aspect of the dynamic tendencies to be expected on the basis of the relief of the substratum (see Map 29).

A comparison of the LANDSAT-I photographs of the *southern part* of the region between the Danube and the Tisza with the early hydrographic map prepared from the first military survey at the time of *Josef II* (see Map 8) immediately reveals hat the present bed directions and the arrangement of the bends differ greathly from the earlier ones. However, major roles were played in these differences not only by the elimination of bends and other regulations, but also by the natural development of the rivers; this stands out most clearly if the state of those meanders not eliminated since the end of the 18th century is compared with the picture of the present water network. In those river sections which have continued permanently to develop in a natural way, a *southward shift* of the meanders can be observed.

Particularly in squares C/6, C/5, D/4 and D/3 of LANDSAT photographs nos. 16 and 22, it is striking that the eastern edge of the Danube flood area, the district of the one-time Vörös swamp, was the swamp area with the most constant nature in the Danube valley. However, a swamp world of a similar character was also formed in the narrow right-hand valley plain of the Tisza (mainly north of Algyő) before the river regulation. In this section too, nevertheless, there still remained the characteristic difference between the swamp areas of the Danube and of the Tisza that was observed further to the north: while the bed of the Tisza was accompanied directly

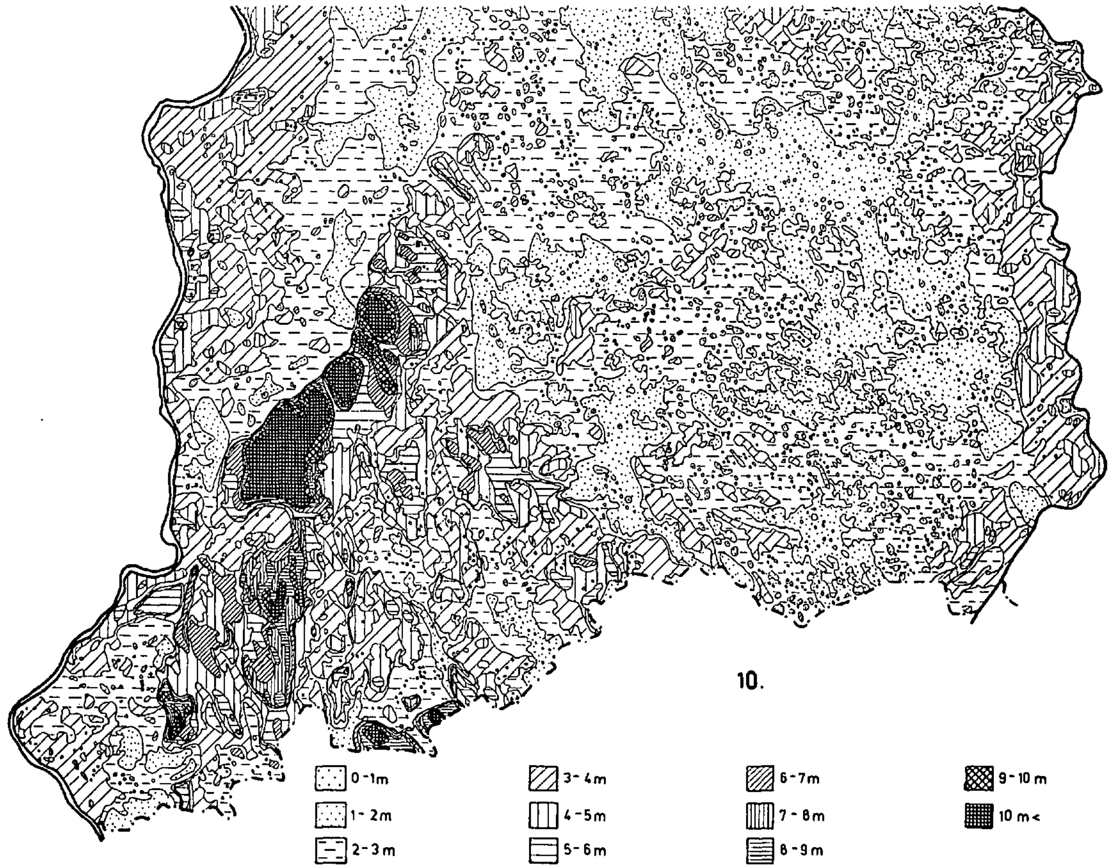


Fig. 10. Groundwater surface depth map of southern part of region between the Danube and the Tisza (RÓNAI—BOCZÁN)

by the swamp zone, in the Danube plain higher flood plains too inserted themselves between the bogs and the bed of the river, only narrower floodwater streams and narrower water strips of early abandoned beds being found in these flood plains.

In comparison with the surfaces of the Tisza flood plains, which display a finer evening-out and a gentler microrelief, the surface of the Danube plain, which bears evidence of extremely densely and finely traced fluviatile work, reveals special hydrologic features. The main cause of the differences is very probably to be sought in the fact that, even long ago, the floodwaters of the Danube were icy floodwaters formed as a result of the high level of ice blocks; in the Tisza, however, because of the ice-loosening roles of the close-lying mouths of the Körös and the Maros, the possibility for the ice to float downstream was more favourable even before the regulation work. Thus, the bulk of the floodwaters here were caused by the summer floods which were slower and had a lower drift height.

The hydrographic conditions of the *table-land* on the southern half of the region between the Danube and the Tisza also reveal sharply perceptible differences as regards the aspects of the loess plateau and the sandy surfaces. Whereas the loessy area exhibits a very poor surface hydrography, small constant and periodic waters occur densely in the depressions and deflational lowland of the sandy zones. The primeval hydrographic map indicates that earlier these not very extensive surface standing waters were present even more densely in the eastern half of the area.

This circumstance (at least in part) is almost certainly responsible for the fact that the impermeability of the sediments is higher in the eastern area of the table-land, and hence at the time of the snow-melting in the spring and in other periods when the water level is high the percolating groundwater too comes to the surface more often, and even water courses may result from this. The Kőrös-ér, which can be examined extremely well in the section between 1/5 and 1/6 in photographs nos. 19 and 20, must be regarded as in part having such genetics. This streamlet runs southeastwards from the direction of Kunfehértó; its wide lowland plain was depicted as a linear bog zone in the early maps from time of Josef II.

It should be noted finally that the directions of the axes of the standing waters on the table-land are in the majority of cases parallel to the predominant wind direction and also reflect the general sloping of the area. The elongation of these lakes in the NW-SE direction, therefore, at the same time indicates that their basins must be conceived of as surface depressions deepened out by deflation (and possibly blocked by aeolian sedimentation). Besides the deepening of the bed by deflation, howerer, at the times of the spring snow-melting and in periods and years with higher than average precipitation a role may also have been played in the further forming of the depressions by the resulting surface streamlet network and the groundwater seepage, and hence a certain secondary fluviatile character too may have been established in some places.

4. Check on the surface geologic, pedologic and geomorphologic features of the region between the Danube and the Tisza on the LANDSAT-1 photographic material

It must be stated that the information given by a detailed study of the satellite pictures and by a comparative evaluation of the petrology and geology of the region, together with its soil-quality conditions and its geomorphologic features, strongly support one another. For just this reason, however, it is difficult to assess the extent to which the indications on the satellite photographs are reflections of the petrologic, the pedologic or the geomorphologic characteristics. The truth is probably that the various geoscientific approaches developed from a regional analysis of the surface substrate in accordance with different aspects and aims, and it is therefore not possible to expect mutually contradictory or a completely new type of knowledge in research divided into these branches. The relief, the forms and the sediments, and the soil layer covering the sediments, are not only in harmony with one another, but also faithfully reflect the natural forces and processes giving rise to them. The surface of the natural landscape is a combined material and relief-quality product of the primeval geographical events of the preceding periods.

Naturally, however, it is a product not only of these. In addition to the natural factors developing the landscape, an ever increasing role is to be observed in the activity of the human society. The replacement of the naturally-occurring vegetation by completely new and forced vegetation structures; the changing of the spontaneous surfaces (e.g. as a consequence of ploughing); the extension of the hydrologic network with new lines, and the constraining of water into these; the extension of artificially (though generally involuntarily) induced soil-degradation spots; reorganization of the relief in accordance with the conceptions of road, railway and settlement development-industrial, mining and urbanizational constructions; etc. These all force "interfer; ing" signs onto the natural picture of the landscape, and even on the synoptic satellite pictures taken from a height of several hundred kilometres these signs sometimes appear much more strongly than the traditional geoscientific indications. Some of the areas in the photographs that we had to interpret revealed literally nothing but the various agricultural plots with different intensive densities.

Thus, if we wish to understand the satellite picture with regard to its geologic and geomorphologic information content, the anthropogenic landscape features must be removed, and the photograph must be compared with geoscientific maps of the landscape, prepared in the traditional manner, by the compilation and fitting-together of a mosaic. This aim is served by the geological maps 11 and 12, which we prepared on the basis of the 1:25,000 scale sheets of the Hungarian National Geological Institute, supplementing these in places with the data of material collected by our Department; by the soil-quality maps 13 and 14, which are based on the STEFANOVITS—SZŰCS recordings; and by the geomorphological maps 15 and 16, which we constructed on the basis of the "Geomorphological map of Hungary", published by PÉCSI in 1967, and in some minor areas on the basis of our own investigations. For control of the various economic geographic consequences, we compiled and plotted on integrated map sheets the already known sites of occurrence of peat. lacustrine and meadow limestone, soda, gravel and sand of importance to the building industry (Maps 17 and 18) in the region between the Danube and Tisza. Finally, we tried to check the extent to which the petrologic and geologic conditions characteristic of the surface

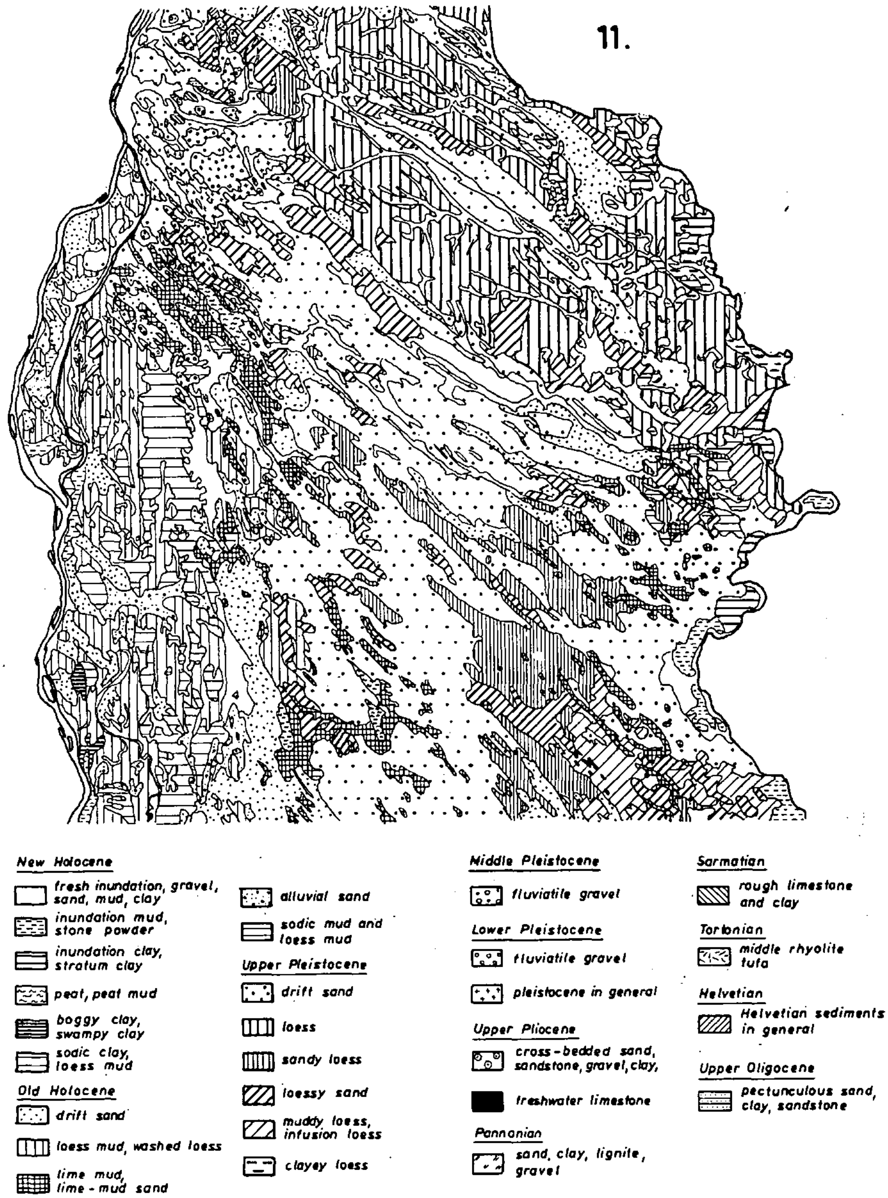


Fig. 11. Geological map of northern part of region between the Danube and the Tisza (MÁFI—JATE)

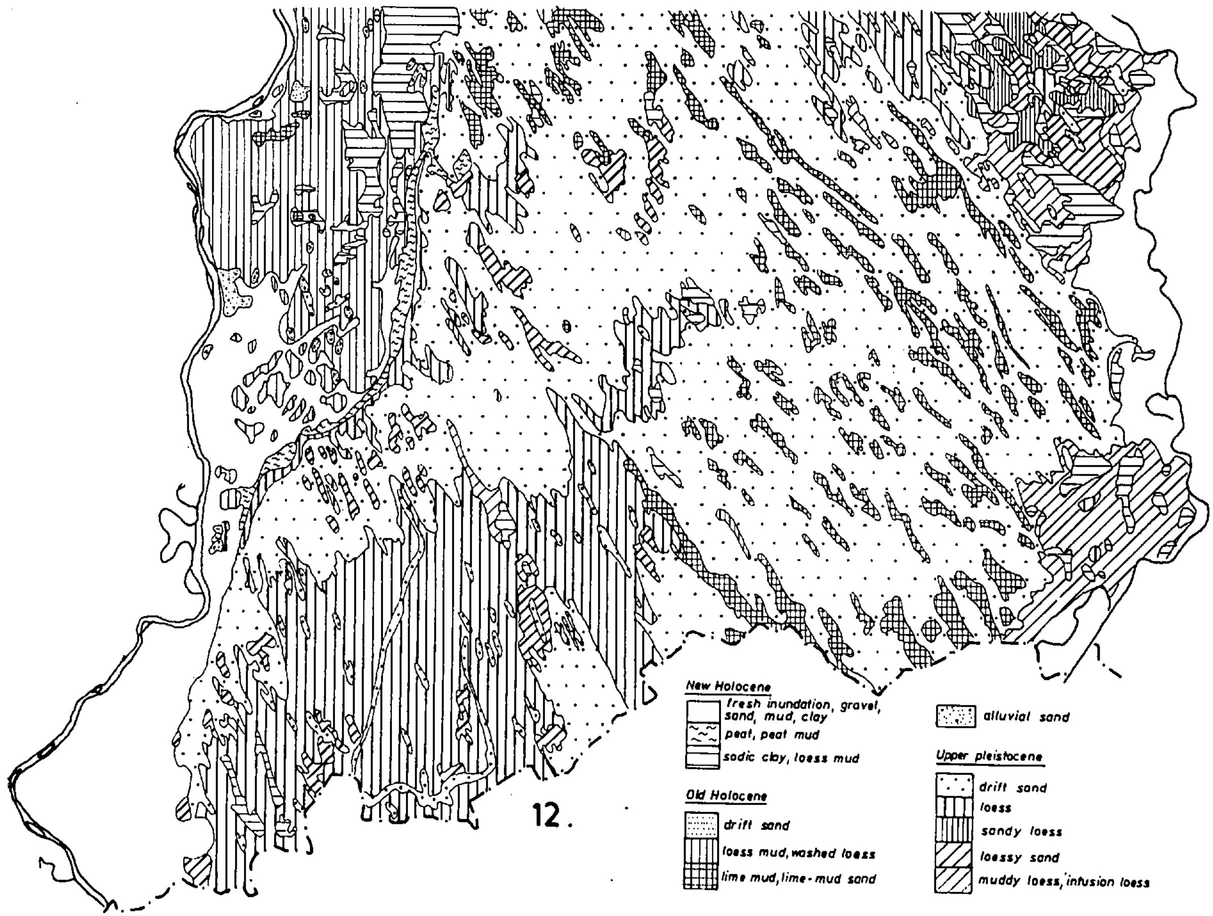


Fig. 12. Geological map of southern part of region between the Danube and the Tisza (MÁFI—JATE)

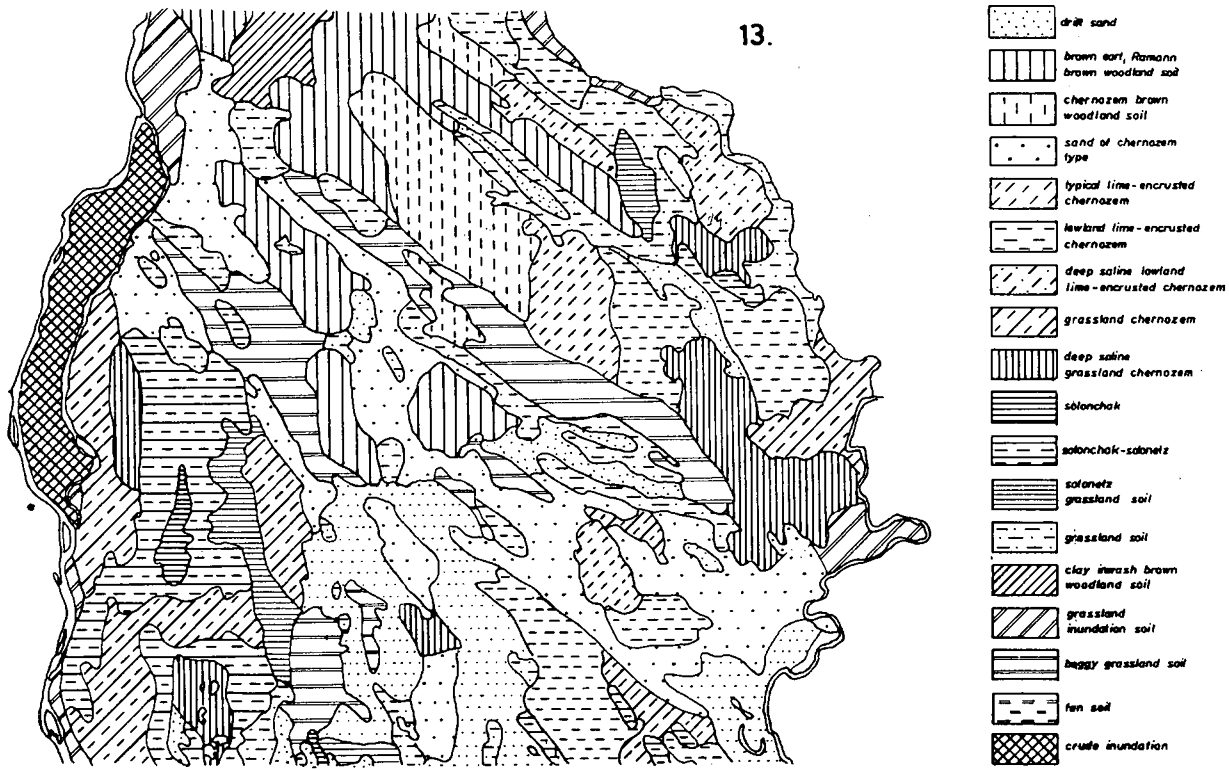


Fig. 13. Soil types of northern part of region between the Danube and the Tisza (STEFANOVITS—SZŰCS)

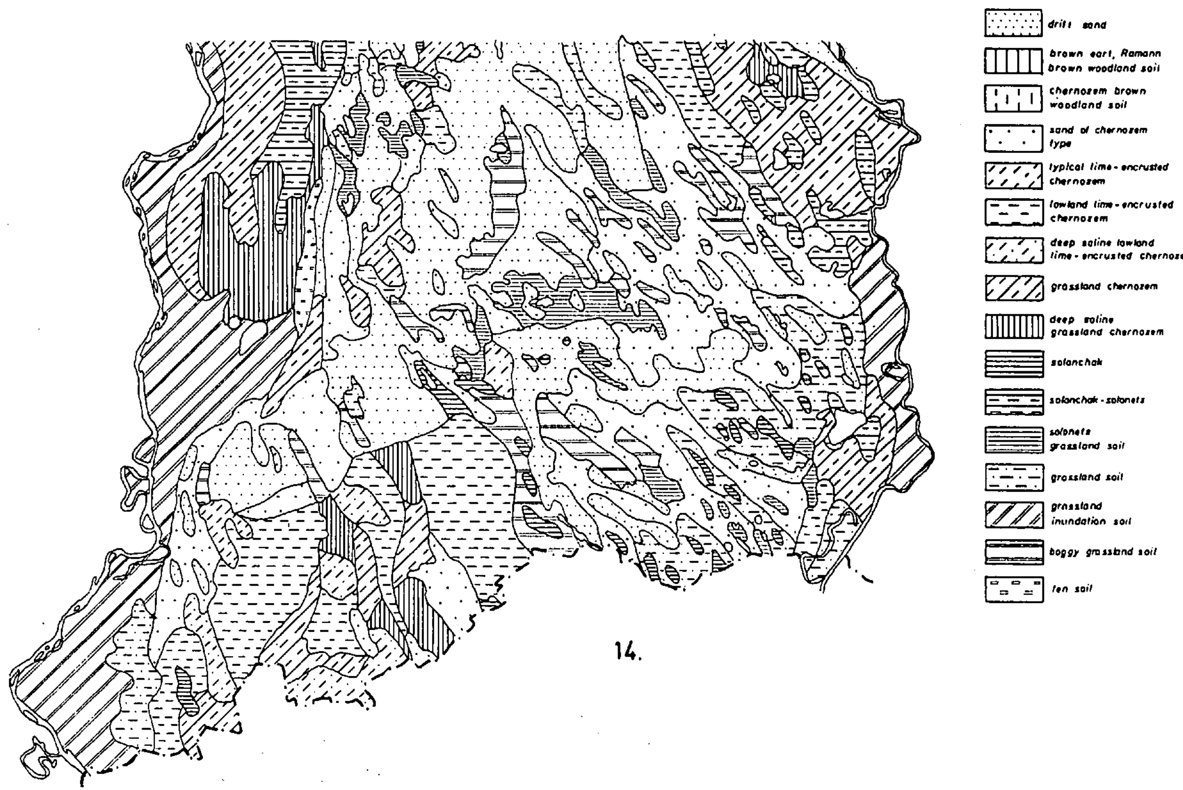


Fig. 14. Soil types of southern part of region between the Danube and the Tisza (STEFANOVITS—SZŰCS)

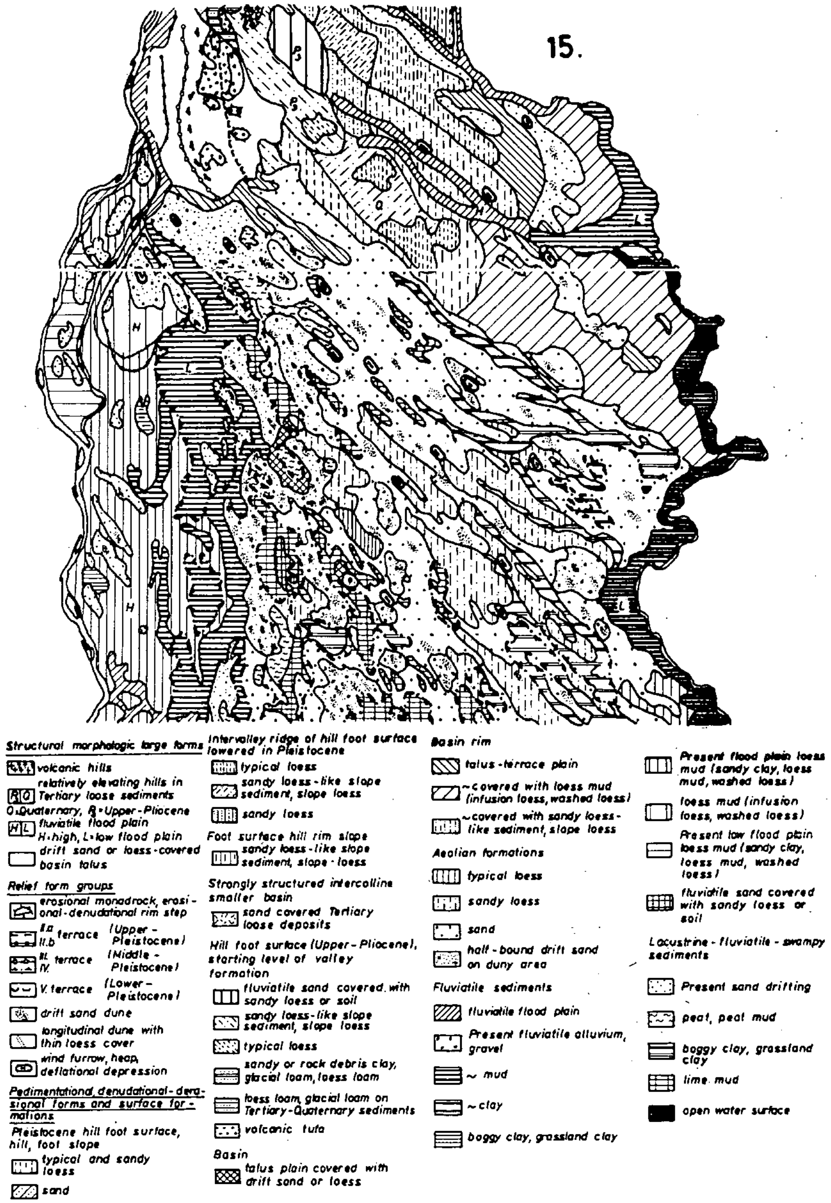


Fig. 15. Geomorphological map of northern part of region between the Danube and the Tisza (PÉCSI)

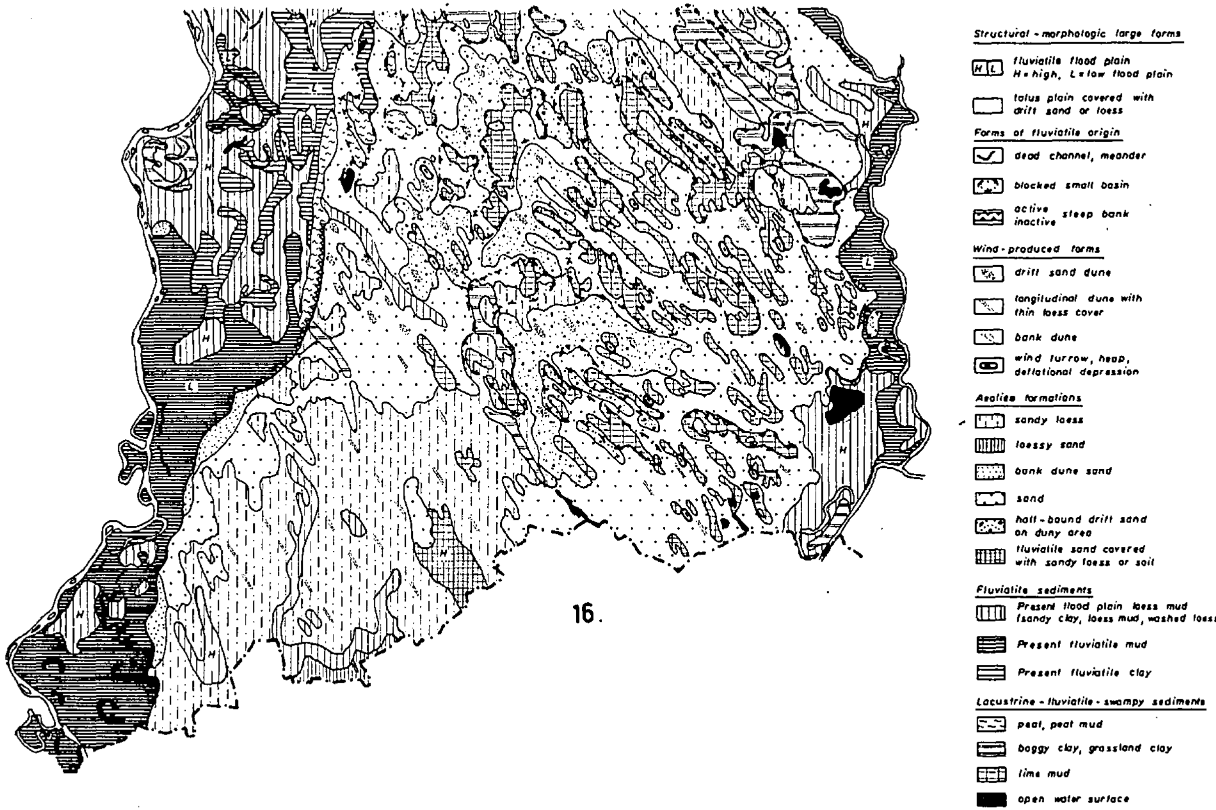


Fig. 16. Geomorphological map of southern part of region between the Danube and the Tisza (PÉCSI)

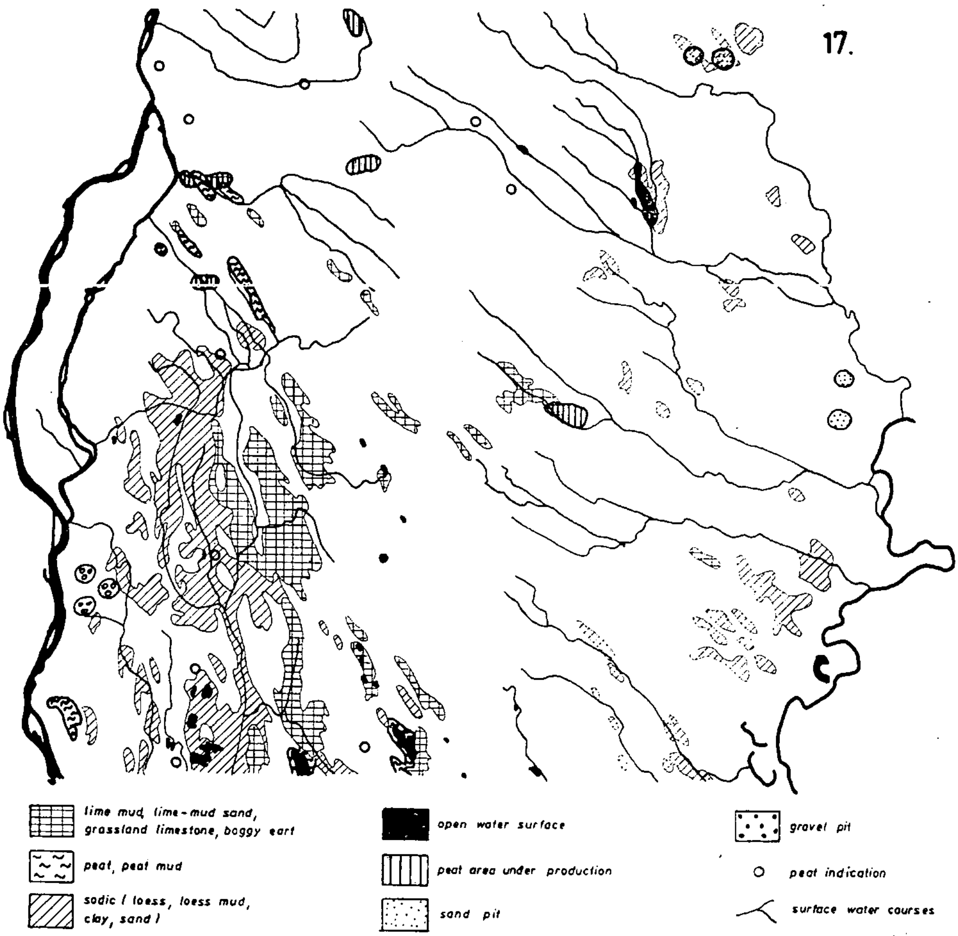


Fig. 17. Areas of occurrence of building industry materials and other useful raw materials in northern part of region between the Danube and the Tisza (MEZŐSI; JATE)

are modified at greater depths beneath the surface. To assess this, we examined the layer sequences of borings made to depths of more than 50 m (possessing the appropriate documentation), and from these constructed the regional porosity percentage maps of the strata at depths of 0—50 m below the soil surface (Maps 19 and 20) for the region between the Danube and the Tisza.

Comparison of the auxiliary maps and the satellite photographs proves that the petrologic and geologic developments in the region between the Danube and the Tisza are in a very close parallel not only with the primeval geographical conditions and with the sedimentation factors determining the early facies arrangement, but also with the processes forming the surface of the landscape both after the sedimentation phases and at present too. The areal distribution order of the soil quality proves essentially the same, though here the pedogenetic factors prevailing at present play

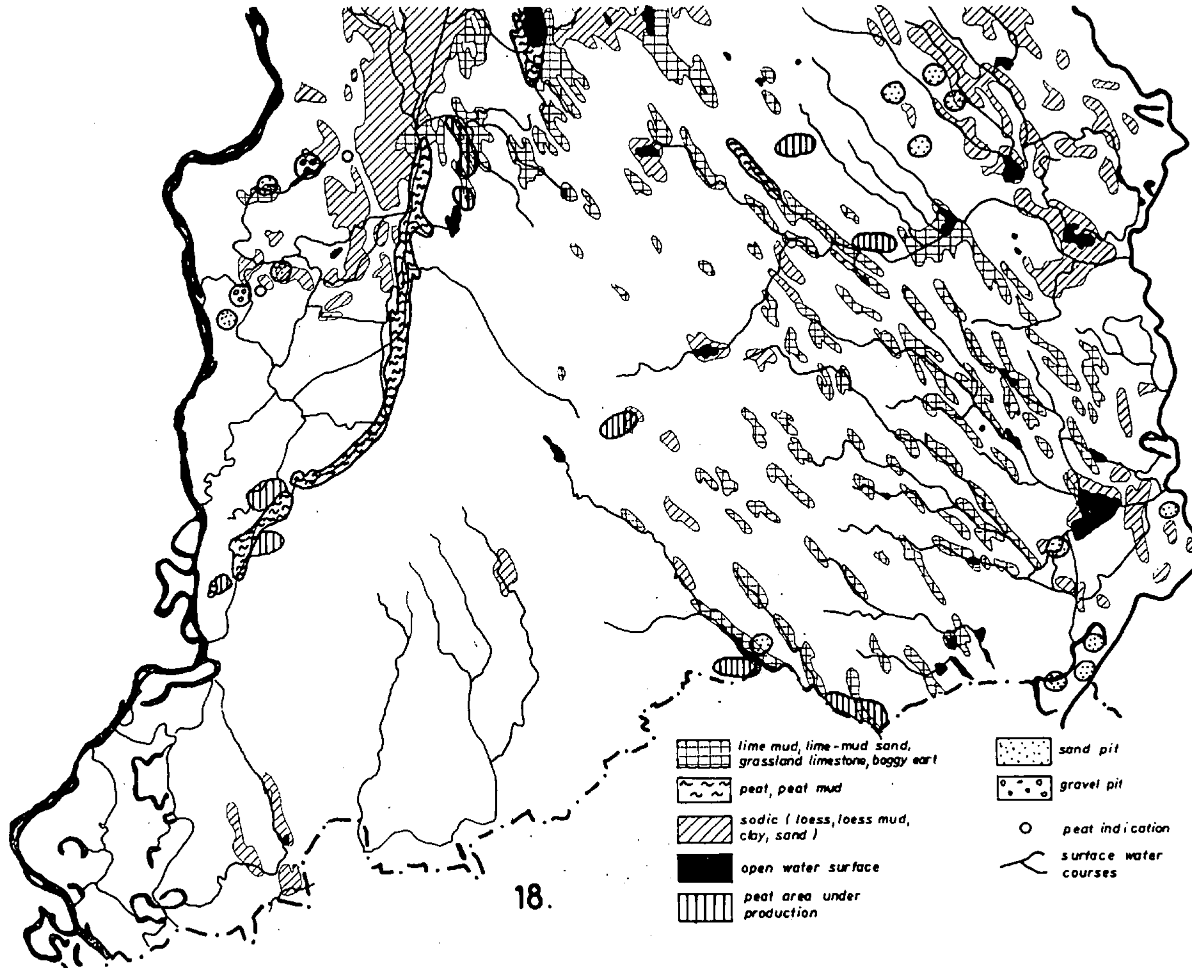


Fig. 18. Areas of occurrence of building industry materials and other useful raw materials in southern part of region between the Danube and the Tisza (MEZŐSI; JATE)

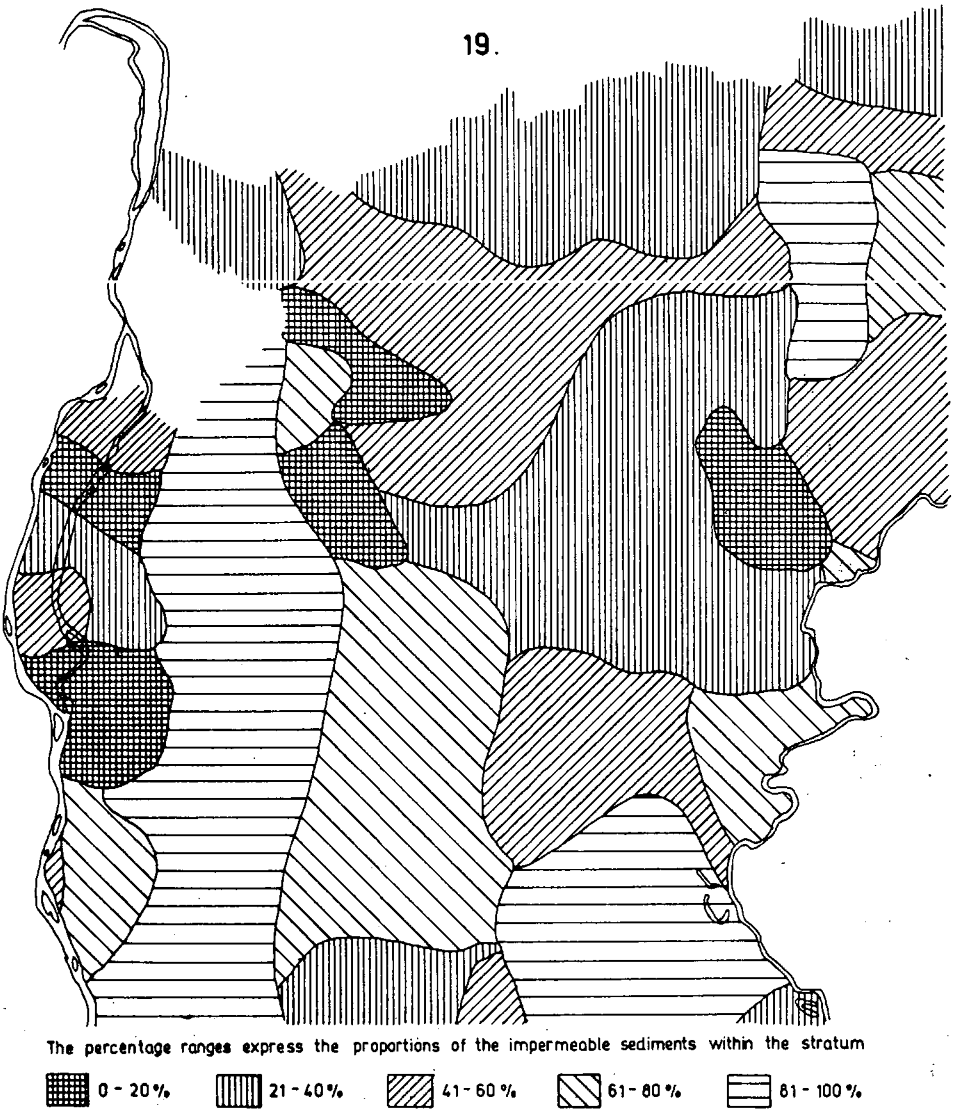


Fig. 19. Porosity percentage map of 0—50 m subsoil strata in northern part of region between the Danube and the Tisza (ANDÓ; JATE)

the greatest role. Perhaps the most fundamental criterion of the morphologic aspect of the surface is that, although complex processes are reflected in the landscape, the main morphogenetic factor is nevertheless essentially the taluses and the alluvial flood plains, and further the series of aeolian sediments, in places covered with loess, and elsewhere covering the loess.

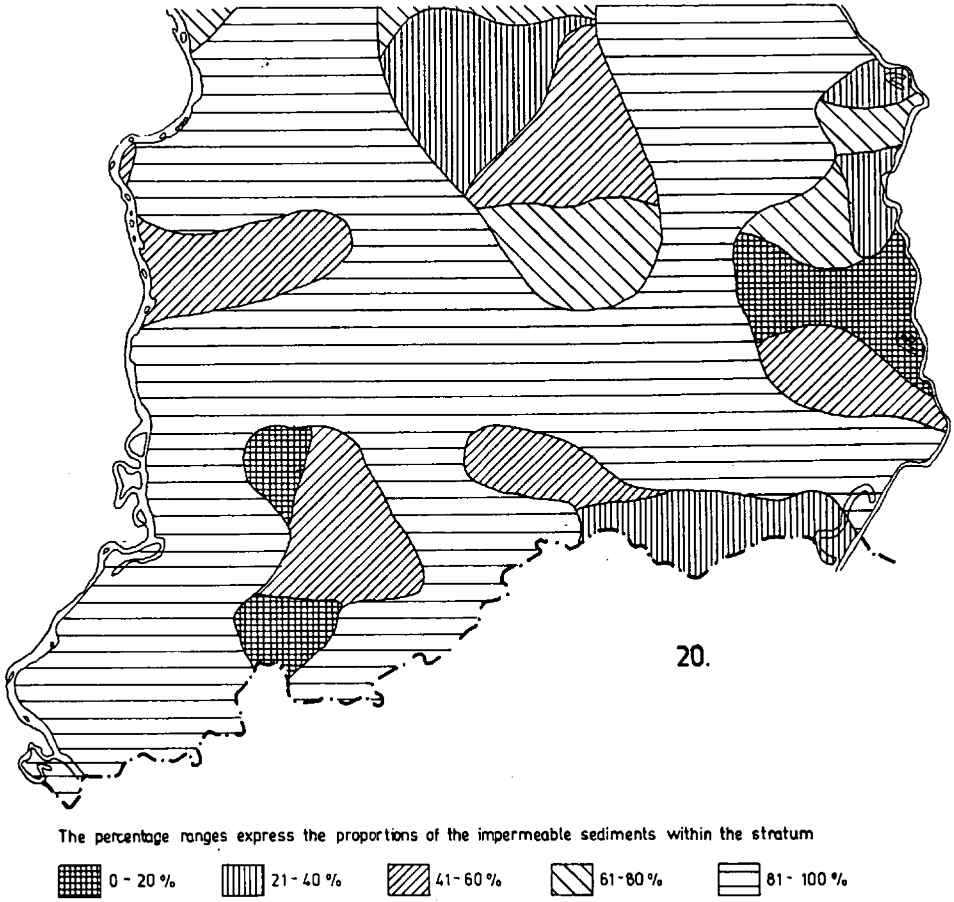


Fig. 20. Porosity percentage map of 0—50 m subsoil strata in southern part of region between the Danube and the Tisza (ANDÓ; JATE)

On the basis of the conditions of development of the rocks and soil, and also the surface morphology, the region between the Danube and the Tisza can be divided into seven well-differentiated areas:

1. The hilly district of Gödöllő and the knolly district of Monor-Irsa.
2. The sandy table-land between the Danube and the Tisza.
3. The loess table between the Danube and the Tisza.
4. The Pest basin.
5. The potamogenic plain of the Danube valley.
6. The potamogenic plain beside the Zagyva.
7. The potamogenic plain of the Tisza valley.

A summary is given below of our interpretation material relating to these areas.

The geologic structure of the *hilly district of Gödöllő and the knolly district of Monor-Irsa* is fairly simple in so far as the knolls on the higher terrain are covered by streaks of loess, the slope rims are covered in places by sandy loess and loessy sand, and the intercolline plains are covered by Upper Pleistocene drift-sand. It appears that the large forms of the areas covered with loess, sandy loess and in places drift-sand are determined in their main arrangement by the preformation of the young tectonic lines, and the small forms by linear and areal erosion, as well as by derasion, in accordance with the higher relief energy.

In agreement with the petrological conditions, the hill ridges are covered by the RAMANN brown forest soil and the chernozem brown forest soil, while the wide flat areas with a NW-SE strike direction are covered by chernozem-type sand, meadow soil and boggy meadow soil.

Unfortunately, the agreement with the series of layers from depths of 0—50 m beneath the soil surface is not so clear-cut, though it is undoubted that, on proceeding from the Danube Bend towards Szolnok, the sediments display a definite refinement. If the Danube talus origin of the deeper sediments is confirmed here, this observation may be indicative of the sectional lowering of the beds in a transverse direction; however, if the aeolian deposits are in the majority in the series of layers, the refinement in the south-easterly direction may be correlated with the increasing distance from the centre of the area from which the material was blown. The material examinations necessary to decide this question form a task for the more distant future.

The *sand table between the Danube and the Tisza* is covered by Pleistocene drift-sand (now generally bound), which becomes progressively thinner on proceeding from the north-west and in general from the direction of the western edge towards the south-east. Sandy loess and infusion loess belonging to the older loess series, as well the loessy sand series, emerge in patches here and there from below this drift-sand surface. Because of the thinning of the sand cover in the eastern half of the table-land, the loessy fractions become increasingly predominant, and simultaneously the infusion character of the loess fractions is enhanced; this is indicative of the higher situation of the groundwater in the vicinity of the Tisza flood plain, and of the fact that inundations originating from the groundwater become more widespread.

On the western edge of the table-land, lime mud too appears as a characteristic postsedimentation deposit in the depressions; this is a sign that these depressions were periodically, but frequently and systematically, filled with standing water. The carbonatic solutions of the waters of the area, concentrating in the flat lowlands, very frequently with the aid of biogenetic factors, resulted in the occurrence of lime mud or boglime layers. In contrast with the limemud sands accompanying the Tisza valley, however, the sedimentation medium here was not the high-level groundwater, but the precipitation water collecting in the wind-carved bogs. This can be seen from the fact that the satellite photographs show the lime patches of the sand table-land standing out with somewhat more striking colours than their environment, while the Tisza valley lime muds can not be perceived (generally below soil level).

Otherwise, *sodic muddy deposits* are also to be found frequently on the bottom of the deflationary depressions of the table-land. In the intense alkalinification processes, the determinants of the sodic soil type were sodium salts, as well as calcium and magnesium-containing solutions.

As regards the *types of the forms* that developed, perhaps the most striking in this region are the wind furrows, the sand dunes and the residual ridges. On the basis of these, the very extensive drift sand area might be termed a "wind-furrowed surface". However, the lower sand forms, the wind furrows, the residual ridges and the deflationary depressions, are characteristic generally of only the eastern half of the table-land, whereas in the west (especially on the rim line in contact with the Danube valley plain) accumulation forms (parabola dunes and sand dunes) larger than these were also formed.

As concerns the *age of the sand movement,* the stratigraphic situation picture permits the assumption that the development of the drift sand areas had already ceased in many places by the very end of the new Pleistocene. In the course of the old Holocene the climate became wetter. The level of the groundwater therefore rose substantially, and thus many areas became swampy on the lower plains of the talus and on the deep-lying parts accentuated by the deflation.

In the hazel-nut period, however, when the climate again became drier than the present one, the drift sand again began to move. In this phase, the sand forms were primarily rearranged on the surfaces possessing medium and higher relief energies. Quite obvious evidence of intensive sand movement in the hazel-nut period is given by the swampy layers buried by sheet sand in the old Holocene, as well as by the sandy soil levels that developed above the loessy sediments in this period. The climate of the present (recent) Holocene, however, is already again more unfavourable for the sand movement, since the level of the groundwater has risen once more, so that the vegetation cover has been able to take root.

Drift sands from the old Holocene, and at times even younger than this, appear in particular on the western rim of the table-land, facing the Danube valley; however, because of the weakening strength of the wind, these no longer extend over to the internal areas of the table-land. The largest continuous such sand field is the Illancs sand district, which can also be interpreted as river-side dune sand. Besides this, however, fairly extensive accumulations of drift sand that was active in the Holocene too are known in places on the western part of this region in particular. These surfaces always appear as islands sharply differentiated from their surroundings, as can be well observed in the area of Tatárszentgyörgy (E/7), to the east of Szabadszállás (E/10), to the south and the north-west of Ágasegyháza, at the Bikatorok (G/10), in the areas of Izsák and Bugac, etc. The greatest thickness of the drift sand in these places attains even 15—20 m.

The horizontal extents of the sand accumulations may also be very different. Some sand accumulations achieve a diameter of more than 10 km.

With regard to the *grain size,* it may be said that in the drift sands on the region between the Danube and the Tisza there is a preponderance of fine-grained sand (0.2—0.1 mm). Only a few sites can be found where medium-sized grains predominate. In the true drift sands (with the exception of the south-eastern areas), the proportion of the very fine fractions is less than 15%. On the ridges covered with loessy deposits, however, the proportion of the very fine grains may reach as much as 25—30%.

The grain diameter examinations otherwise document convincingly the already discussed fact that the sand grains become finer on proceeding from the north-west towards the south-east on the table-land. In certain borings exceptions do arise. However, these are so few in number, or they are found in linear settlements indicative of fluviatile secondary silting, that they in no way refute the generally recognizable tendency.

The genetics can also be controlled on a *grain morphology* basis. The most characteristic formal feature of the drift sands on the table-land is the grain rounding resulting from the high degree of abrasion, while in the fluvial sand the grains are sharp and angular.

As we have seen, the sand layers accumulated aeolically in the Pleistocene were resettled in places in the Holocene too. In the course of such formal rearrangements in the old and new Holocene, however, the fraction not only attained a finer grain size, but at the same time were further rounded. This is well illustrated in the following Table by the numerical data indicating the degree of abrasion of the grains.

In connection with the mode of preparation of the Table, it should be noted that the sand samples were first treated with 10% hydrochloric acid in the laboratory of our Department in order to dissolve out the limestone content; they were next boiled in hydrochloric acid to remove the dolomite particles; subsequently, the well washed and dried (105 °C) samples were sieved, and the grains were classified into the following four abrasion categories with the aid of a binocular streomicroscope:

Grade I: An easily fractured, sharp, angular form, with no sign of abrasion (transparent, shiny).

Grade II: A little splintery; the edges are weakly blunted (semi-transparent).

Grade III: The edges are strongly blunted, but the original form can still be made out (a little lustreless).

Grade IV: Completely abraded; spherical or oval in shape; the original form can no longer be made out (lustreless).

In the assessment of the degree of abrasion, primarily the form was taken into consideration, and the transparency and lustre were only secondary aspects. The resulting numerical values were converted to percentages expressing the distributional proportions of the grains.

From our data representing the W-E directional section of the southern part of the region between the Danube and the Tisza, therefore, on the surface there is no sand deposited directly from the river water. The Table shows that in all samples there is a quantitative predominance of grains of type III, which indicate an aeolian nature. The total amount of the grains of type II comprises about one-third of the whole study material. This in turn means that the aeolian transport was a short-range one.

The *loess table between the Danube and the Tisza* lies in the western quarter of the southern part of the table-land; it is bordered in the west by the valley alluvium of the Danube, in the north by the line Hajós-Kiskunhalas, and in the east by the line Kiskunhalas-Kelebia. In the south the area is limited by the national boundary. It must be noted, however, that this natural geographical and geological landscape unit does not cease at the national boundary, but continues further in the Bácska loess table-land in Yugoslavia, with essentially *unchanged petrologic and morphologic characteristics.* This is naturally so, in spite of the fact that a completely different picture is presented by the photographs of LANDSAT-I.

If the interpretation lattice is placed on the satellite pictures of the southern part of the region between the Danube and the Tisza (e.g. photographs nos. 17, 18, 19 or 22), it is obvious at once that the picture of the landscape changes strikingly along the national boundary. On the Hungarian side of the Bácska loess table and the whole table-land mosaics of smallish patches with different densities are to be seen side by side, whereas on the Yugoslav side are scarcely any such mosaics, the surface of the landscape being much more homogeneous.

However, these clearly seen "national" differences do not have natural causes.

Site of occurrence	Depth m	I	II	III	IV
		grain form			
Petőfi-tó	0.0—0.3	1.5	35.0	60.0	3.5
Petőfi-tó	1.5—1.8	1.0	38.0	58.0	3.0
Petőfi-tó	3.0—3.5	1.0	35.5	60.5	3.0
Petőfi-tó	9.5—9.8	2.0	29.0	65.0	4.0
Soltvadkert	17.0—24.5	—	32.0	63.5	4.5
artesian well	81.0—86.0	—	30.5	65.0	4.5
Szarvastó	0.2—0.6	—	26.0	68.5	5.5
Szarvastó	3.0—3.5	0.5	24.5	70.0	5.0
Szarvastó	7.0—7.2	0.5	29.0	65.5	5.0
Kunfehértó	0.0—0.4	—	22.5	74.0	3.5
Kunfehértó	1.0—1.2	—	24.5	73.0	2.5
Kunfehértó	3.0—3.2	—	22.0	74.0	4.0
Kunfehértó	6.4—6.6	—	29.0	69.9	2.0
Kunfehértó	7.4—7.6	—	30.0	68.0	2.0
Kunfehértó	8.2—8.4	—	27.5	69.0	3.5
Szank	0.2—0.5	—	18.5	74.5	7.0
Csólyospálos	0.2—0.5	—	17.0	76.5	6.5
Csólyospálos	1.8—2.2	0.5	19.5	75.0	5.0
Csólyospálos	4.4—4.6	—	21.0	74.0	5.0
Ásotthalom	0.2—0.5	—	14.0	78.5	7.5

In all probability the explanation is that the timetable of the agricultural work in Yugoslavia differs from that in Hungary: the photograph taken on 18 November reveals that by that date the ploughing of the stubble-fields had already been completed in Yugoslavia, so that the satellite could no longer distinguish differences between the natures of the different strips; in contrast, in Hungary at that time this phase of the agricultural work still largely remained to be done, and accordingly the differences showed up between the different strips with regard to the natures of the crops and the degrees of working.

The petrologic material of the loess table between the Danube and the Tisza is a typically aeolian formation, the bed of which consists of Pleistocene aeolian sand. This is a pale yellow, loosely structured, easily crumbled material, which displays a variable layer thickness (1—12 m). It was formed in the Würm$_2$ and Würm$_3$ glacial period. The drilling studies made by MIHÁLTZ (1950) showed that this material is present everywhere beneath the surface in the western and eastern parts of the tableland; it is missing only in the southeastern section of the central part, in the area between Jászszentlászló, Kistelek and Pusztaszer. In this area, loess formations are found only at greater depths, and are older than the previously-mentioned ones.

As a consequence of mixing, the petrologic composition of the loessy deposits exhibits frequent changes in the developmental border zone of the surface loess layers. Thus, depending on the predominant grain size, both sandy loesses and loessy sands occur, while at the points with a lower-lying terrain there are washed infusion loess formations.

The grain fraction of the infusion loess may also be variable. Various transitions may be observed between the sandy infusion loess, the muddy infusion loess and the clayey infusion loess variants. However, we could not differentiate these loess variants in the satellite pictures.

Mainly soils of chernozem type were formed on the surface of the loess table. In the western half of the table-land the surface is covered by sandy soils of chernozem type, while further to the east the surface is various lime-encrusted or grassland chernozems.

Apart from the relief differentiation (already examined), a separate discussion of the *Pest basin* is also justified by the geologic and geomorphologic characteristics. Deposits from the Lower Pleistocene and older than the Pleistocene have come to the surface at some places in the basin, though these are generally covered by an Upper Pleistocene cover of various thickness, mainly of fluviatile, but in part of aeolian origin. The older Pleistocene compositions are primarily represented by fluviatile gravels, and the layers older than the Pleistocene by cross-layered Pliocene sands, sandstones, gravels and clays, freshwater limestones, Pannonian sands, clays and gravels, in extremely small patches by Sarmatian limestone and Tortonian rhyolite tufa, and finally only in traces by Helvetian and Upper Oligocene deposits (the latter pectunculous sands, sandstones and clays). The freshwater (Pliocene) limestones appearing at the edges of the basin indicate the development of the subsidence of the basin trough as early as the Pliocene.

Overall, therefore, the geologic conditions of the Pest basin reveal that this is a subsidence zone, which was earlier an area with varied stratigraphic and tectonic structure, then in the Pleistocene becoming first the head of the Danube talus, and later an aeolian centre. The aeolian Upper Pleistocene and Old Holocene sands occurring in this area are indicative of the Old Holocene developmental phase.

As regards its geologic, geomorphologic and pedologic conditions, the *potamogenic plain of the Danube valley* is sharply distinguished from the adjacent regional units in the satellite photographs. Various Holocene inundation muds and clays, as well as the strongly washed loessy muds, predominate on its surface, arranged areally in accordance with the erratic meandering of the one-time river beds. At a number of places in the vicinity of the present Danube bed (e.g. in the area of Apostag), sand accumulations blown out of the bed can be seen; these are accumulated in the NW-SE direction, thereby proving that the fundamental process of transformation of the Pleistocene sand areas of the table-land, which were much greater in extent and proportions, was also the activity of a NW wind.

The immediate left-hand bank of the river is accompanied by a low flood-plain terrace, which is covered by loess mud, by sandy clay and by alluvium consisting of washed loessy material. The most marked development of this can be observed in the southern part of Csepel Island in square B/8 of photograph no. 10. This area is connected to an Old Holocene river terrace, generally 8—10 km in width, characterized by similar sediment facies. Its level is situated about 4—5 m higher than the present "low" flood plain of the river.

It is worthwhile to pay attention to the circumstance that there is a broad, low flood-plain band on the eastern edge (in direct contact with the table-land) of the potamogenic plain of the Danube valley; the position and level of this band point to very young fluviatile activity, and possibly subsidence too. Right up to the time of the regulations of the river, there were swampy areas on this low flood plain, which was covered mainly with boggy and grassland clay. This narrow lacustrine zone is accompanied almost throughout by peaty accumulations. Peat was formed from pure peat moss in certain places, and from various swamp plants elsewhere (sometimes with the remains of tree trunks); in this area it occurs with different layer developments and in different thicknesses (0.3—3.0 m) (see Map 18). It is interesting that the analogous peat-bog swamp facies are absent from valley of the Tisza, or show up in only an extremely thin development.

In the eastern rim line of the valley plain of the Danube, to the south of Hajós, the peaty deposits are replaced by lacustrine sand facies. These must definitely be regarded as simultaneous facies of the peaty deposits, and their genetics are to be explained by the more intensive erosional activity of the Danube in this section.

When the sediment strata filling up the potamogenic plain of the Danube are examined, it emerges that the grain composition becomes finer in an upwards direction in the whole fluviatile series. This continues to such an extent that the proportion of standing-water, lymnetic deposits becomes icreasingly more frequent among the ever finer-grained fluviatile sediments characteristic of the upper levels. In the Holocene, the otherwise coarser, and even gravelly outcrops were transformed; erosion beds were carved out of them, and subsequently filled with fine muddy, clayey alluvium. The surface of a considerable proportion of the Danube valley is covered by such a fine-grained, limy, muddy, clayey sediment cover. The muddy layer is generally 2—3 m in thickness, but in the sections of the abandoned meanders and the oxbow lakes it attains as much as 6—8 m in places.

The sediments from the alluvial inundations of the Danube, consisting petrologically of fine sand, loess mud or clay (or mixtures of these), have been classified by some authors in the literature as Holocene-washed loess; however, the correctness of our conception can be proved on the basis of both the settlement structure and the grain composition. The material examined is therefore a sediment with a very compact structure, displaying a high degree of impermeability, and of various shades of colour (yellowish-grey, yellowish-black).

Two characteristically differentiated facies types may be seen in the alluvial inundation on the Danube valley plain. In the northern parts (up to a line between Fajsz and Hajós) the loess mud and the calcium carbonatic sodic loess mud dominate, and here the alkalinification too is well accentuated, in contrast with the more uniform inundations of the more southerly sections. This too otherwise confirms the longer durations of water stagnation and the lasting nature of the water coverage on the flood plain of the river, i.e. almost lacustrine states.

The inundation sediments of the most southerly section of the Danube valley consist of fluviatile inundation sand, mud and clay. Here again a more varied layer development may be observed in the clayey deposits, this occurring in the course of the standing-water sedimentation of the abandoned bed arms.

We have already seen that, as regards its relief conditions, the *potamogenic plain beside the Zagyva* is sharply differentiated from the hilly districts of Gödöllő and Monor-Irsa. This differentiation is not so striking from a geological aspect:

as far as the district of Szolnok and the line of the Zagyva-Tisza, an important role is played in the structure of the surface of the plain by the Upper Pleistocene loess cover, and by the drift sand (similarly Upper Pleistocene) blown out of the previously-discussed intercolline valley systems. On proceeding from the west towards the east, the petrologic facies on the plain replace one another in the following sequence:

1. Basin rim sandy slope sediments, covered with slope loess.
2. A basin rim terraced talus plain.
3. Present fluviolacustrine sediments and drift sands.
4. Basin rim sediments covered with infusion and washed loess.
5. Low flood-plain clays.

This facies arrangament convincingly supports the strongly subsided basin nature of the area, and its fluviatile sedimentation cycle of hill-foot talus origin.

On the right-hand bank of the river, the *potamogenic plain of the Tisza valley* does not exhibit a broad, interconnected alluvial band. Instead, the Holocene alluvia accompanying the river are isolated from one another, as a consequence of the already frequently-mentioned circumstance that the river underwent a westward shift in this section, and at present too erosion is forcing the Holocene valley plain ever further to the west. The mud-covered low flood plains are therefore in contact erosionally and directly with the aeolian areas of the table-land. Particularly sharp erosion rims developed on the line of contacts with the loess facies, and also in those places where the drift sand virtually lay on the side of the river (see, for example, the high bank between Tiszakécske and Alpár).

In places a small thickness of sand has even in the present age advanced onto the Recent potamogenic accumulations. This conforms the aeolian genetics of the table-land sand, and at the same time demonstrates that the western border of the Tisza valley did indeed arise from the equilibrium of the combined activities of aeolian accumulation and fluviatile erosion. In contrast with the loess facies contacts, however, these contact boundaries do not stand out sharply orographically.

5. Research into the signs of the theoretically conceivable effect connections in the integration of the deep-structural conditions of the region between the Danube and the Tisza and the surface phenomena groups observed by satellite

As emerged above, in the course of the evaluation of the material of the satellite photographs we were able in some areas to identify properties relating to the relief, hydrography and surface petrographic distribution, and in some cases these properties may be assumed to be correlated with crustal structure phenomena and with local crustal processes exhibiting a tendency to elevation or subsidence. If these assumptions are correct, it is conceivable that the deep-geological conditions may support the consequences of the surface analysis; on the basis of known analogies, there are many reasons for us to believe that the nature and the magnitude of the areal structural movements are permanent and consequent over a long geological period. In this sense, therefore, information on the surface dynamics may be of assistance in the research of at present still unknown deep structures in which the occurence of useful industrial raw materials (such as hydrocarbons) is not excluded.

In accordance with these considerations, we have attempted to compare the

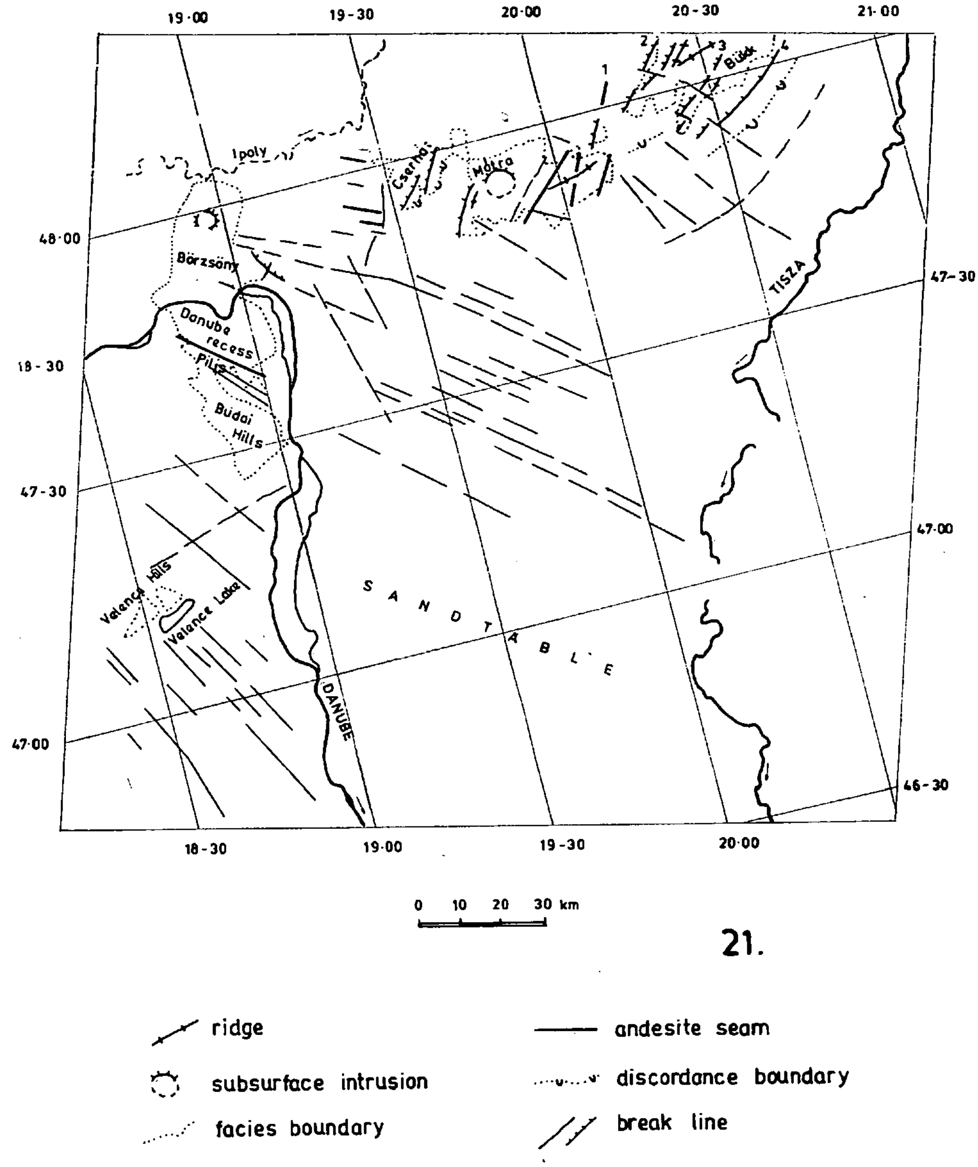
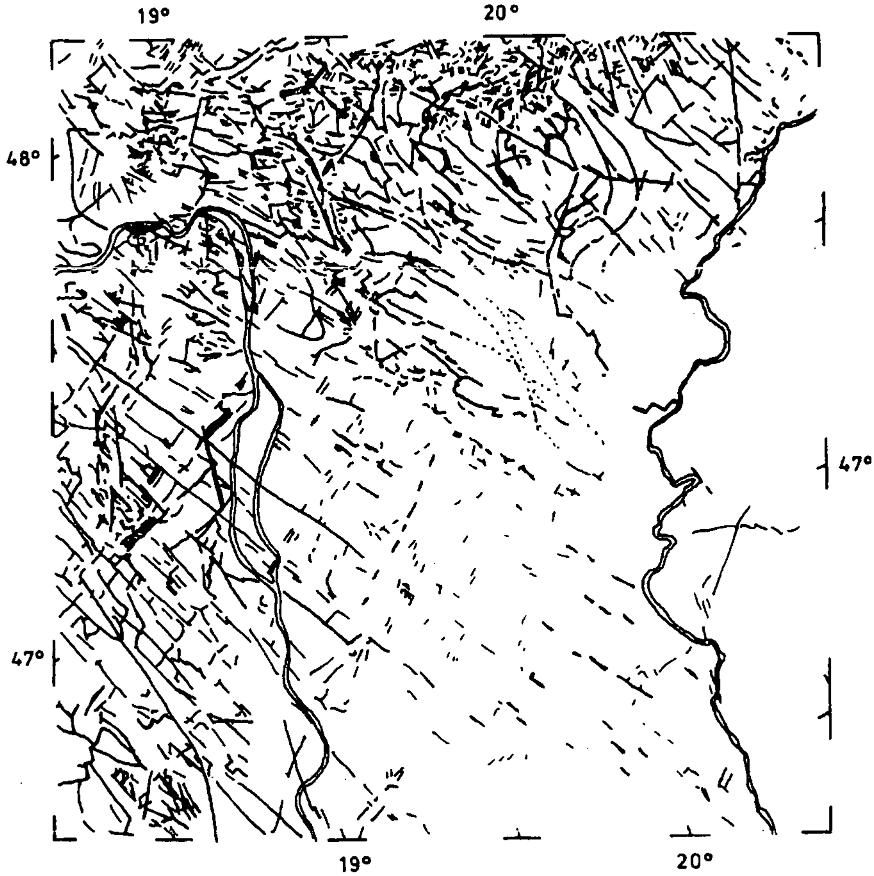


Fig. 21. Tectonic sketch of the Danube Bend and the Northern Low-mountains (CZAKÓ)



22.

Fig. 22. Tectonic interpretation of ERTS—1 photographs of northern part of region between the Danube and the Tisza (RÁDAI)

different deep-geological, deep-structural and geophysical information with the surface observations at those points where the indications of the satellite pictures make this appear reasonable.

Comparison of the tectonic picture resulting frcm the interpretation of the LANDSAT photographs with the conception of the deep-structures yielded by other means was made particularly justified by the circumstance that an increasing number of authors have in recent times tried to consturct such dislocation maps purely from the information of satellite photographs. In Maps 21, 22 and 23 we present the (in many respect mutually contradictory) experiments of CZAKÓ, RÁDAI and

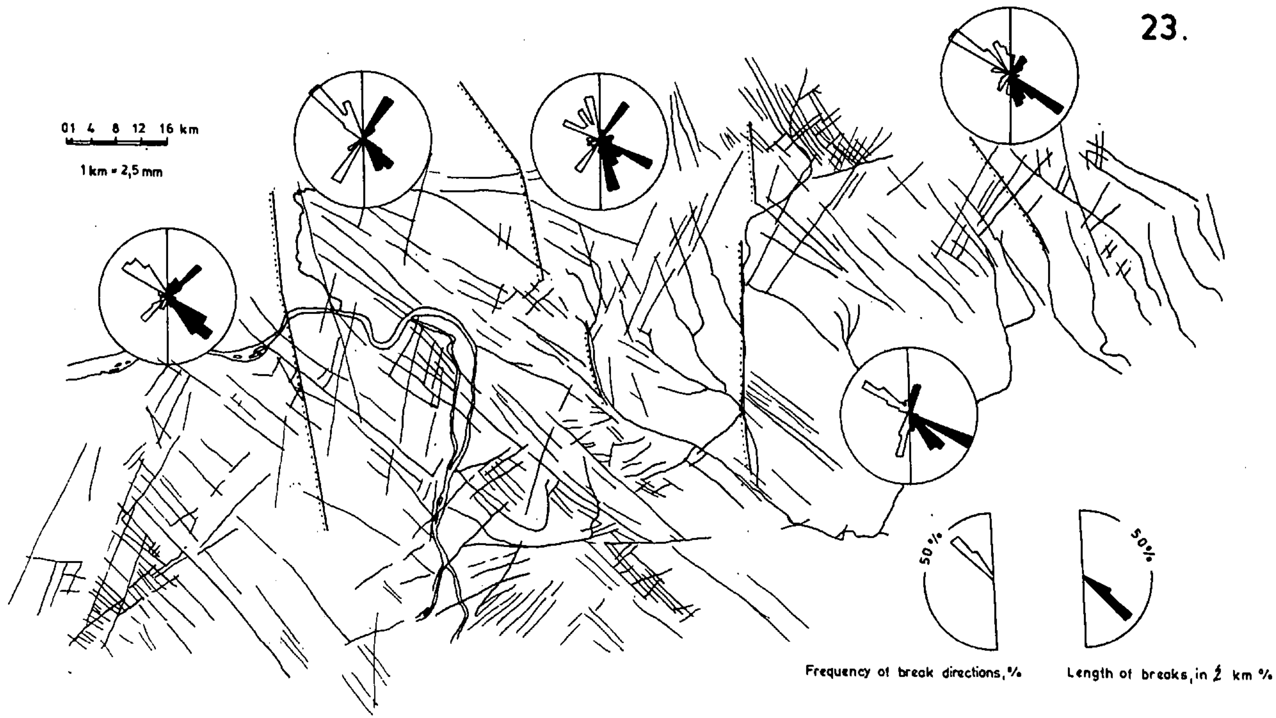


Fig. 23. Tectonic interpretation of ERTS—1 photographs of North Hungary and northern part of region between the Danube and the Tisza (ORAVECZ)

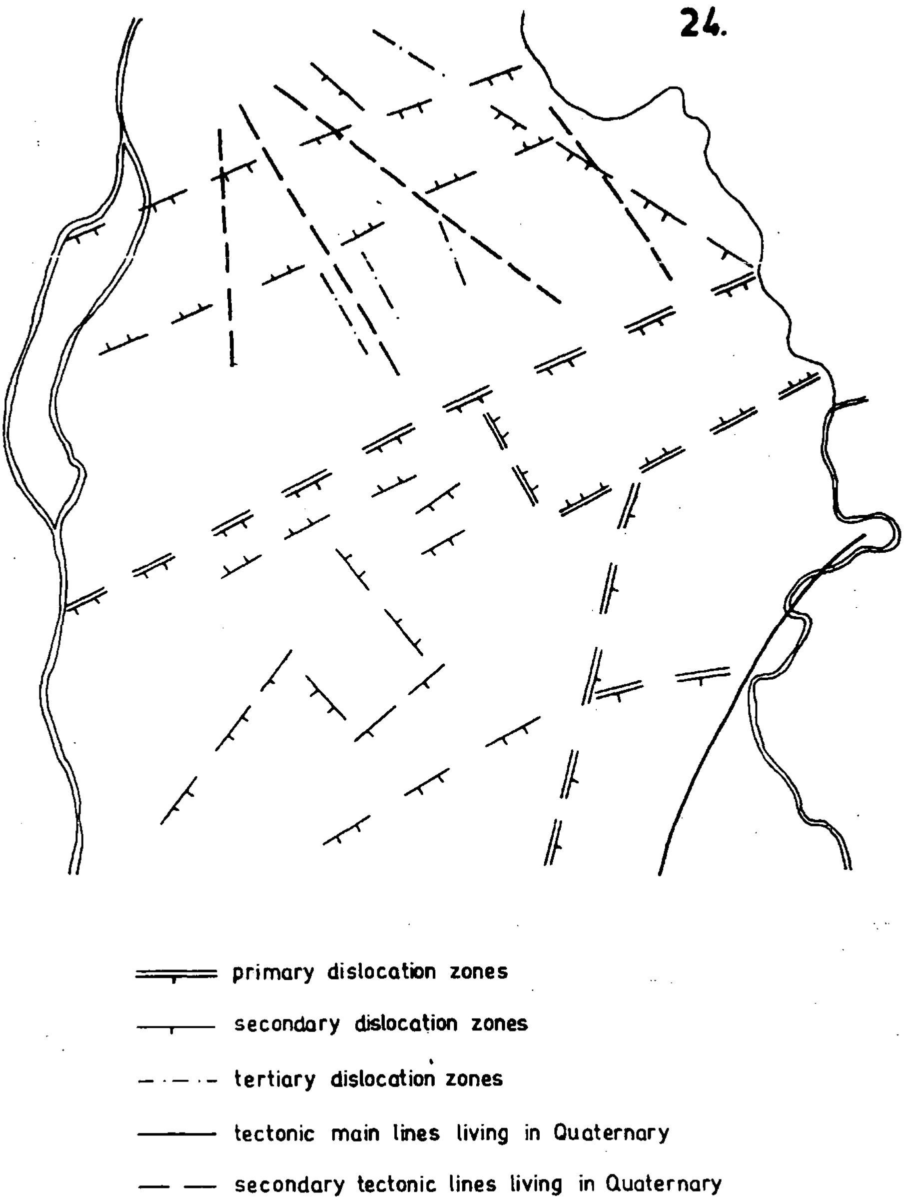


Fig. 24. Diaclase belts and Quaternary-active tectonic lines of northern part of region between the Danube and the Tisza (constructed from data of KŐRÖSSY and RÓNAI by MEZŐSI; JATE)

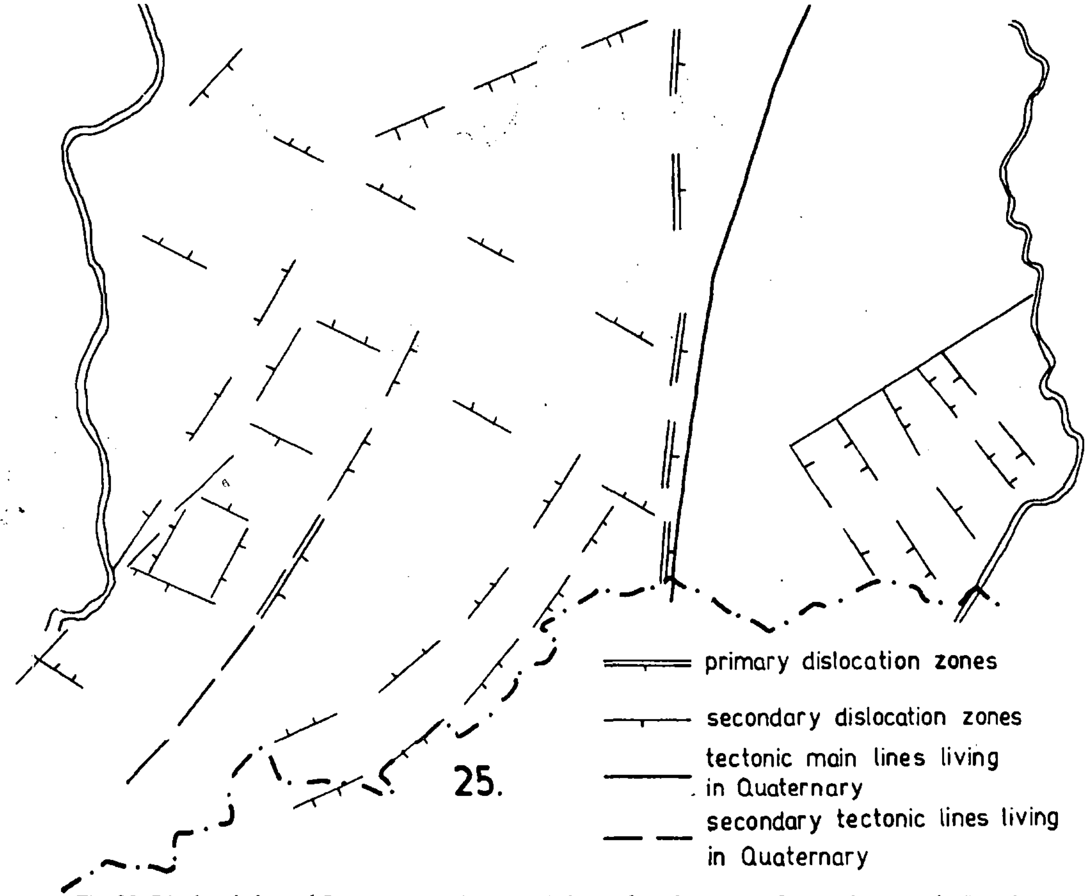


Fig. 25. Diaclase belts and Quaternary-active tectonic lines of southern part of region between the Danube and the Tisza (constructed from data of KŐRÖSSY, KOVÁCS and RÓNAI by MEZŐSI JATE)

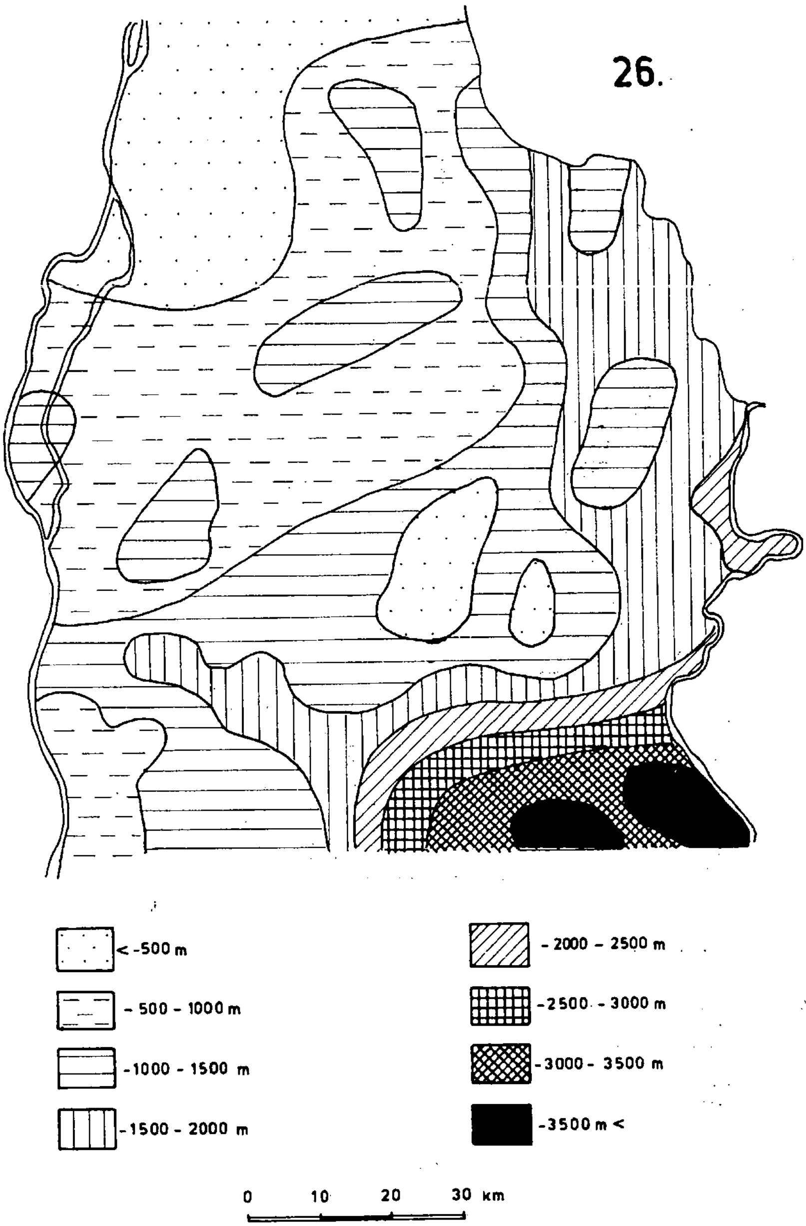


Fig. 26. Basin-bottom map of northern part of region between the Danube and the Tisza (KERTAI)

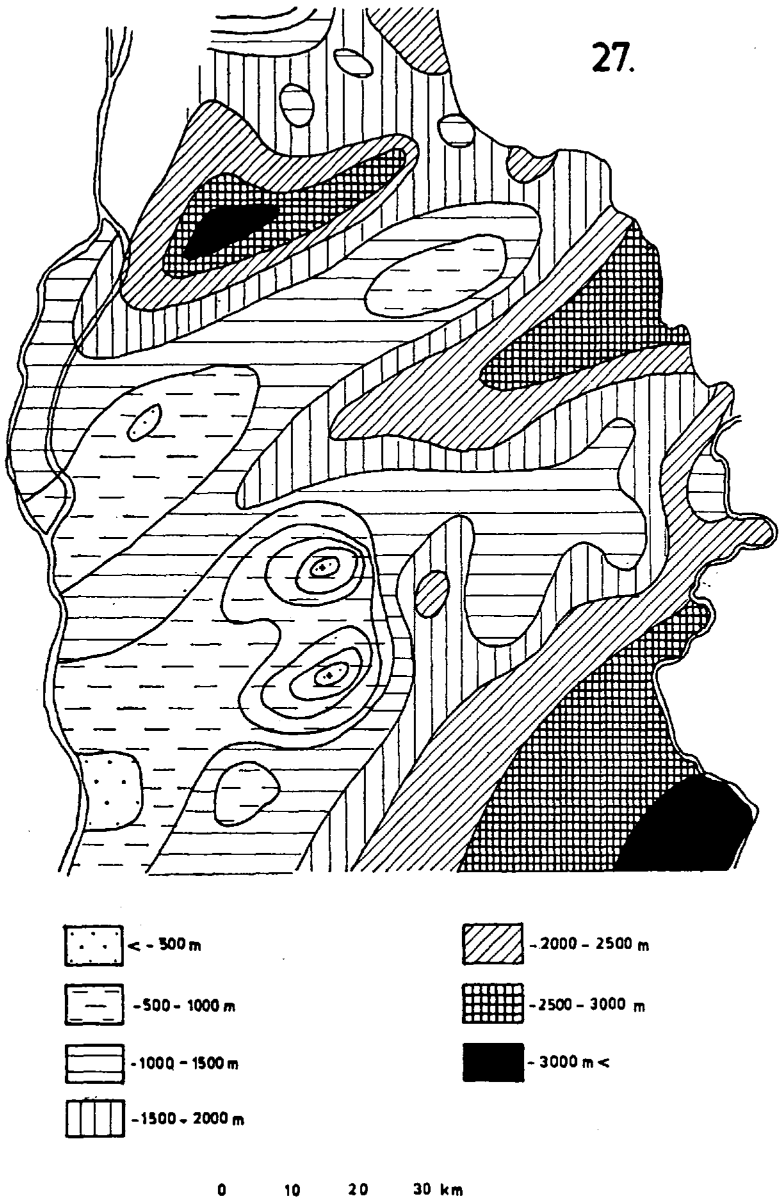
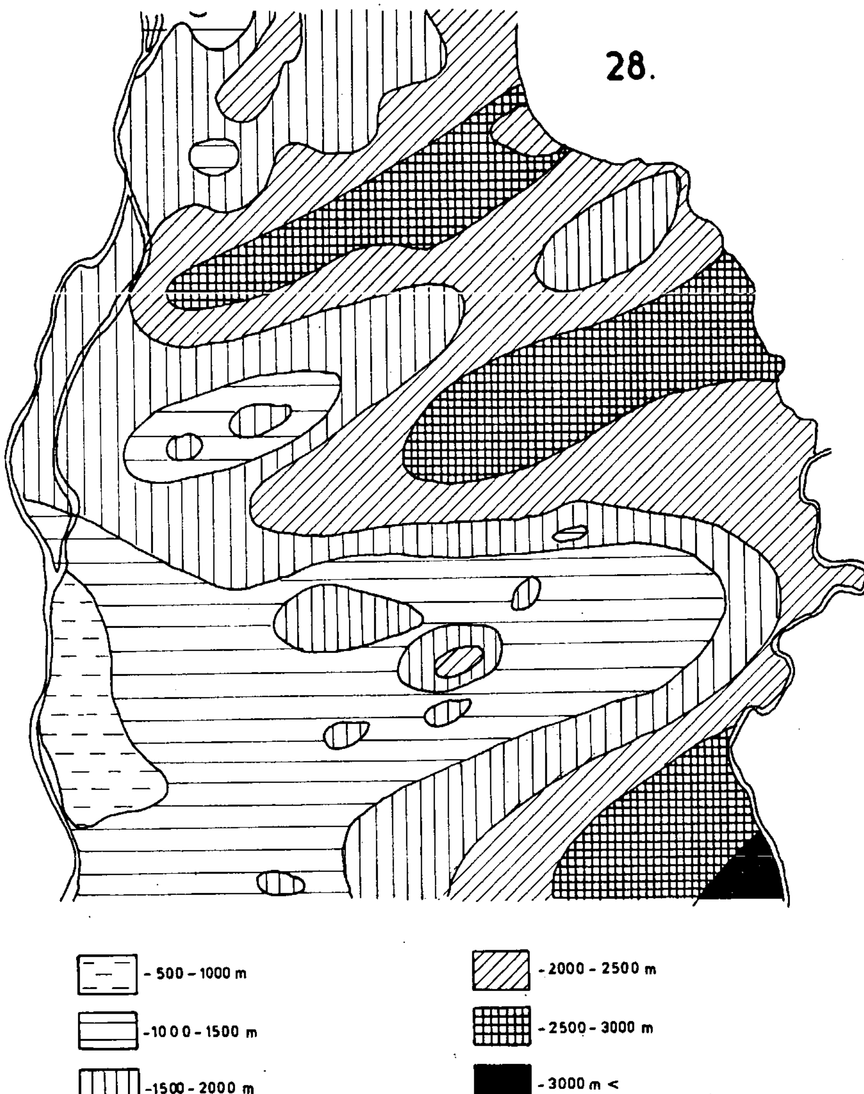


Fig. 27. Basin-bottom map of northern part of region between the Danube and the Tisza (BALOGH)



0 10 20 30 km

Fig. 28. Basin-bottom map of northern part of region between the Danube and the Tisza (JUHÁSZ)

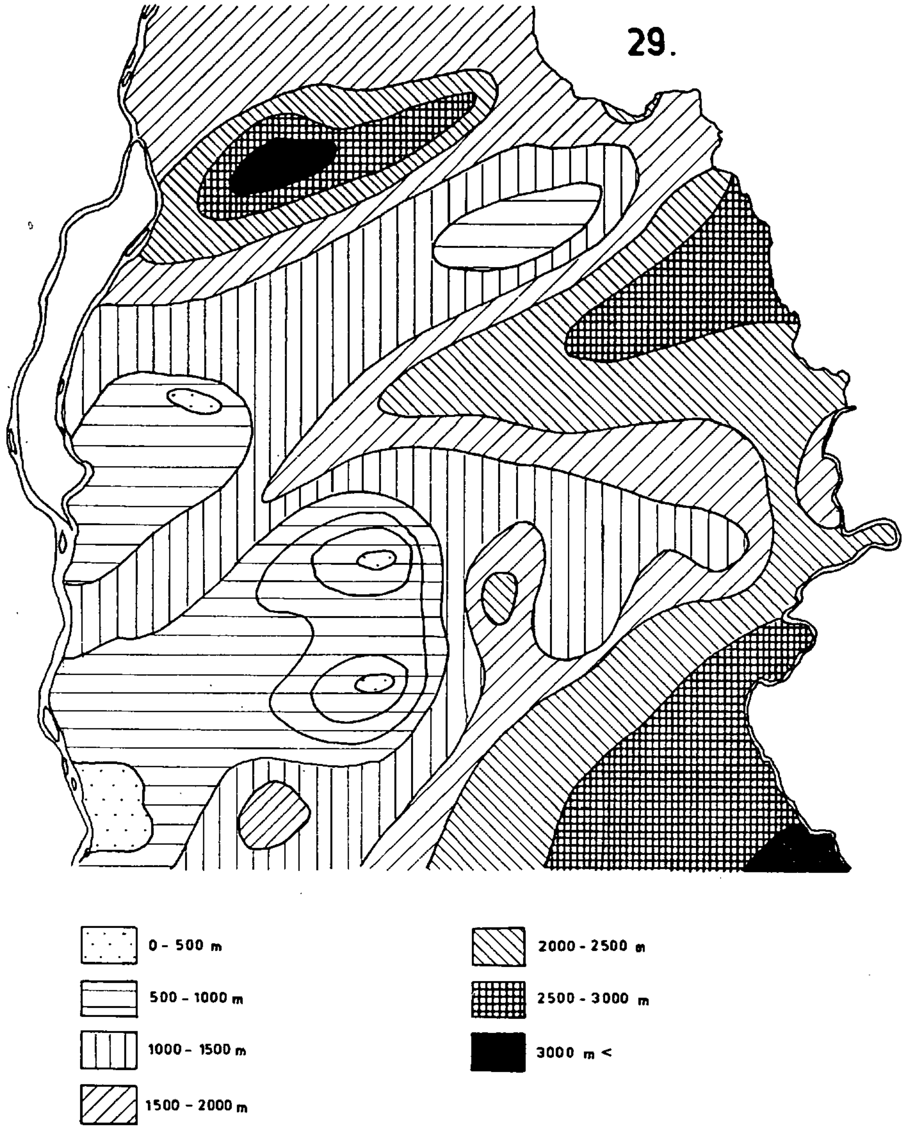


Fig. 29. Substratum topography of northern part of region between the Danube and the Tisza (JAKUCS—FEHÉR; JATE)

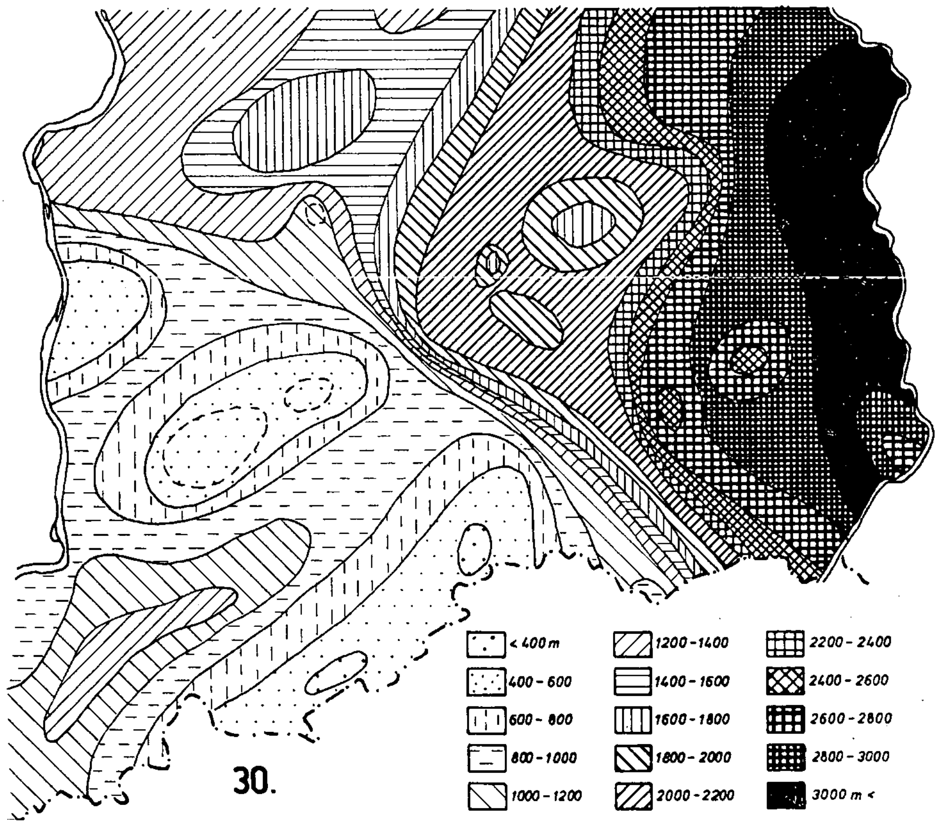


Fig. 30. Basin-bottom map of southern part of region between the Danube and the Tisza (JAKUCS—FEHÉR; JATE)

ORAVECZ, who published tectonic satellite interpretations on mainly the northern half of the region between the Danube and the Tisza.

It appears quite definitely that those lineaments which figure in these maps are not always true structural features; in some cases they are rather denudation lines conforming to the water and valley networks, the directions of the aeolian ablation, or the borders of the petrologic facies zones, which in the majority of cases are not preformed with dislocations.

The drawings of the various authors otherwise contain different lines, and features considered of importance by one authors are at times not even observed by another. All this is evidence that a very large role may be played in the interpretation of the zonal boundaries on satellite photographs of terrains covered by fluviatile and aeolian accumulation by subjectivity (and creative fantasy).

The contradictions are especially evident if we compare the information content of Maps 21, 22 and 23 with the deep-structural diaclase belts and tectonic lines constructed on the basis of the publications by KŐRÖSSY, KOVÁCS and RÓNAI (see Maps 24 and 25). Compared to the former, these latter sketches are undoubtedly

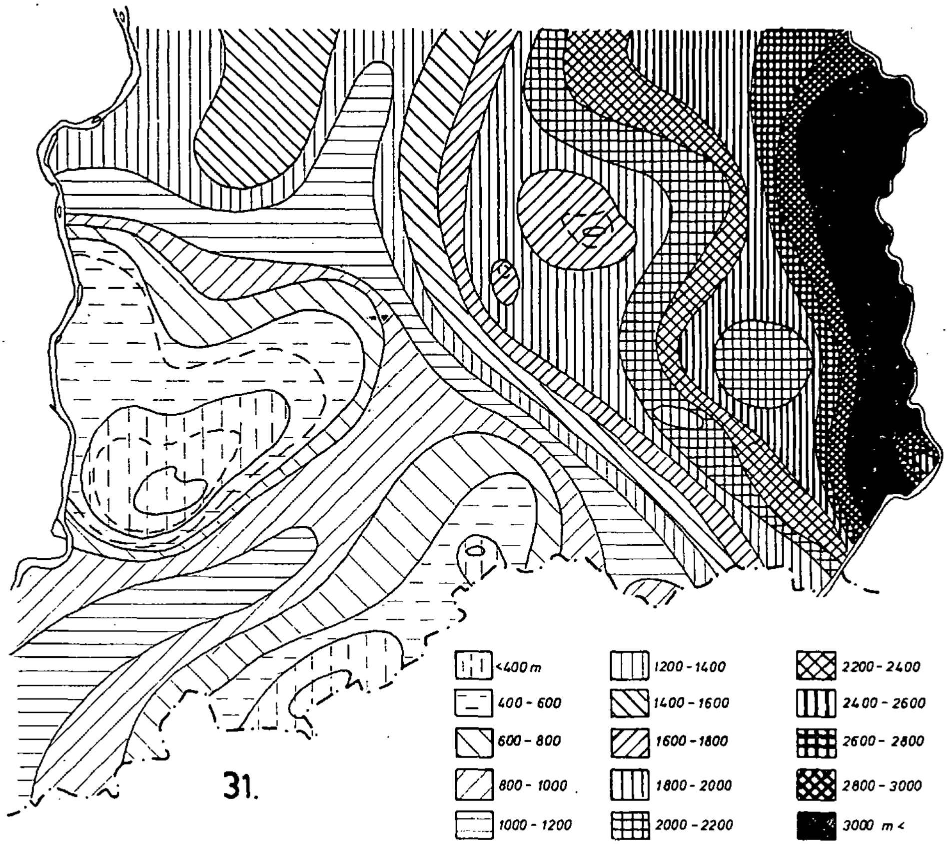


Fig. 31. Lower Pannonian bed map of southern part of region between the Danube and the Tisza (JAKUCS—FEHÉR; JATE

supported from the aspects of many more investigations, and in a deep-structural sense they are essentially more objective. As concerns the tectonic utilizability of the contents of the LANDSAT-I photographs of the region between the Danube and the Tisza, however, it is just these serious discrepancies which hamper the development of a realistic attitude.

From the aspect of the assessment of this topic, which is also of interest as regards scientific theory, our Department is in the fortunate situation that between 1968 and 1970 we carried out detailed research into the connections between the surface and deep-lying geoscientific phenomena in the region between the Danube and the Tisza, in particular with regard to hydrocarbon prospecting. Within the framework of this research the National Mineral Oil and Gas Industry Trust (OKGT) then provided us with all of the available documentation on the deep-boring material and stratum investigations, and in part with the aid of these we constructed the substratum relief maps of the region (Maps 29 and 30), the Lower and Upper Pannonian bed maps of the southern part of the region between the Danube and the Tisza

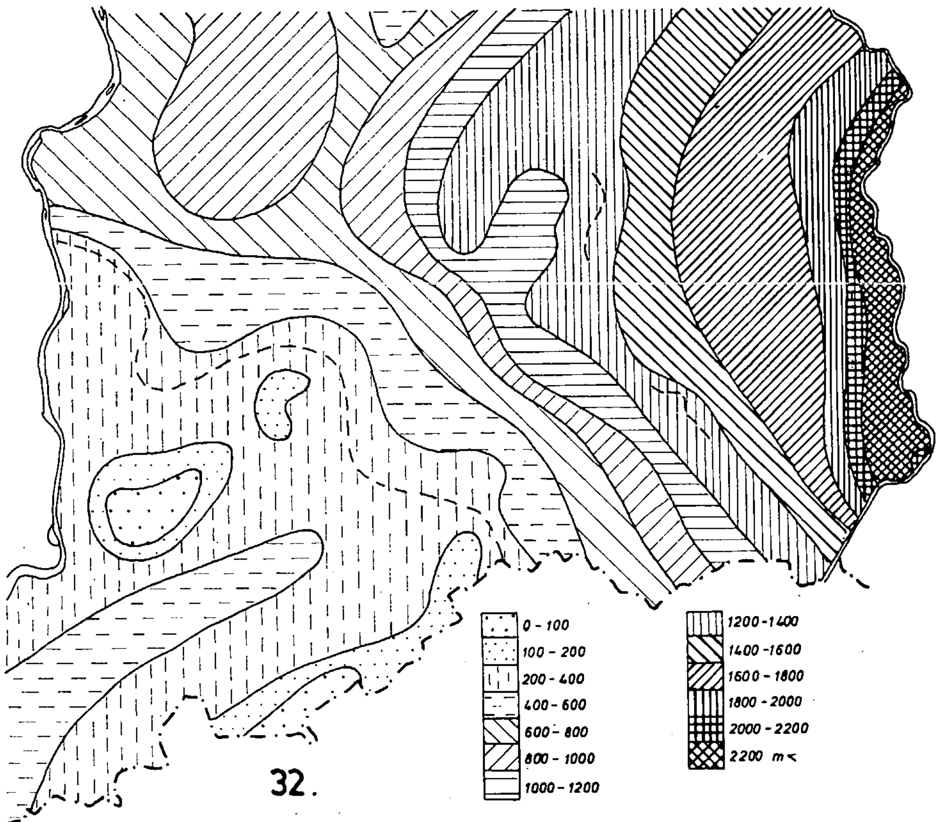


Fig. 32. Upper Pannonian bed map of southern part of region between the Danube and the Tisza (JAKUCS—FEHÉR; JATE)

(Maps 31 and 32), and also the geothermal gradient map of the northern part (Map 42). At the same time we made a thorough study of the basin floor maps consructed by earlier authors (KERTAI, BALOGH, and JUHÁSZ) (Maps 26, 27 and 28), as well as the gravitational and geomagnetic maps of the Geophysics Institute (Maps 33, 34, 35 and 36). Besides our own geothermal gradient map (Map 42), we also took into consideration the often mutually seriously contradictory compilations of BOLDIZSÁR, URBANCSEK, BENDEFY and STEGENA (Maps 39, 40, 41 and 43), and finally we processed the recent geokinetic data of BENDEFY too (Maps 37 and 38). All this information was then taken as basis in the integration of the deep-structural conditions and the surface phenomenon groups observed by satellite.

What emerged as the most marked tendency during the comparative evaluation was the permanent *process of subsidence* of certain parts of the region, lasting since the end of the Tertiary, but with rates varying locally. The most intensive subsidence centres are on the eastern edge of the region between the Danube and the Tisza, mainly along the south Tisza valley, in the areas of Csongrád-Szeged. In accordance

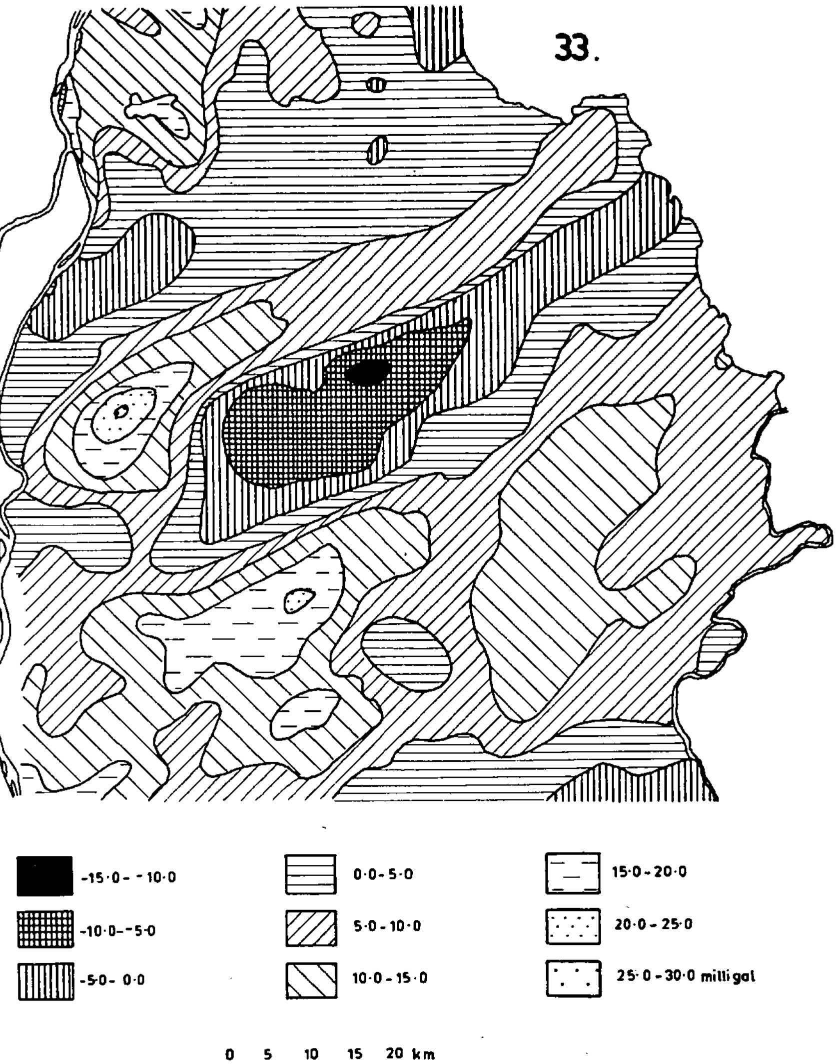


Fig. 33. Gravitational map of northern part of region between the Danube and the Tisza (ELGI)

with the satellite observations, this is documented by the relief of the Paleozoic-Mesozoic surface of the substratum map (Map 30), and also by the maps of the Lower and Upper Pannonian bed levels (Maps 31 and 32), the geokinetic map of the southern part of the region between the Danube and the Tisza (Map 38), and the relief (Map 2), relief energy (Map 4), geomorphologic (Map 16) and geologic (Map 12 and 13) maps depicting the surface conditions.

It is by no means a chance phenomenon, therefore, that the lowest-lying points

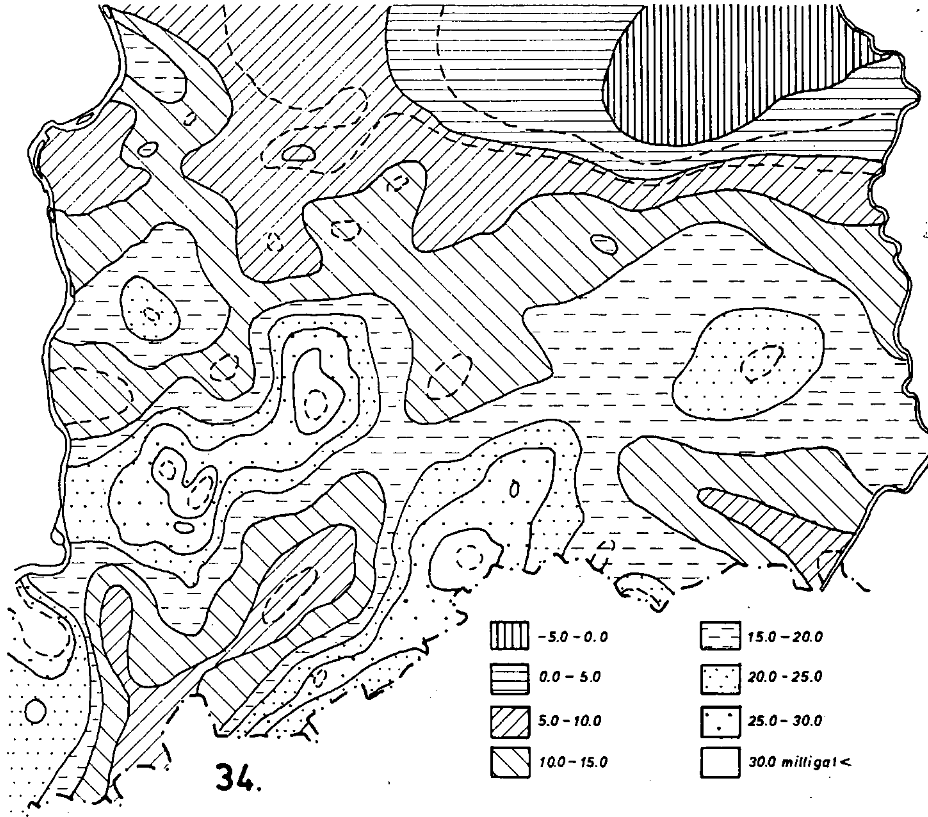


Fig. 34. Gravitational map of southern part of region between the Danube and the Tisza (ELGI)

above sea-level in the region between the Danube and the Tisza are to be found in the section of the south Tisza valley, and that the flood plains in the Danube sections with equivalent widths lie at higher levels. The difference in level of about 10 m between the alluvial plains of the two rivers may be attributed to the different magnitudes of the recent subsidences of the various areas. Without this, the situation would be just the reverse: the flood plain of the Tisza should have a much higher level, since the accumulation of the Tisza valley occurred not only in a fluviatile process, but also aeolically, under the action of the north-westerly winds. This means that the dynamics here were essentially faster than for the flood plain of the Danube valley, where only fluviatile forces were involved in the accumulation, but where in addition material was lost as a consequence of the deflational proceses. In the light of our research, it appears that the dynamics of accumulation of the alluvium were about ten times greater in the Tisza valley than in the Danube valley. If the surface of the Tisza valley is nevertheless not higher than that of the Danube valley, therefore, this must mean that the rate of subsidence of the area of the Tisza valley was *at least ten times* that of the Danube valley.

This is otherwise proved by the heavy-mineralogic and grain-abrasion investi-

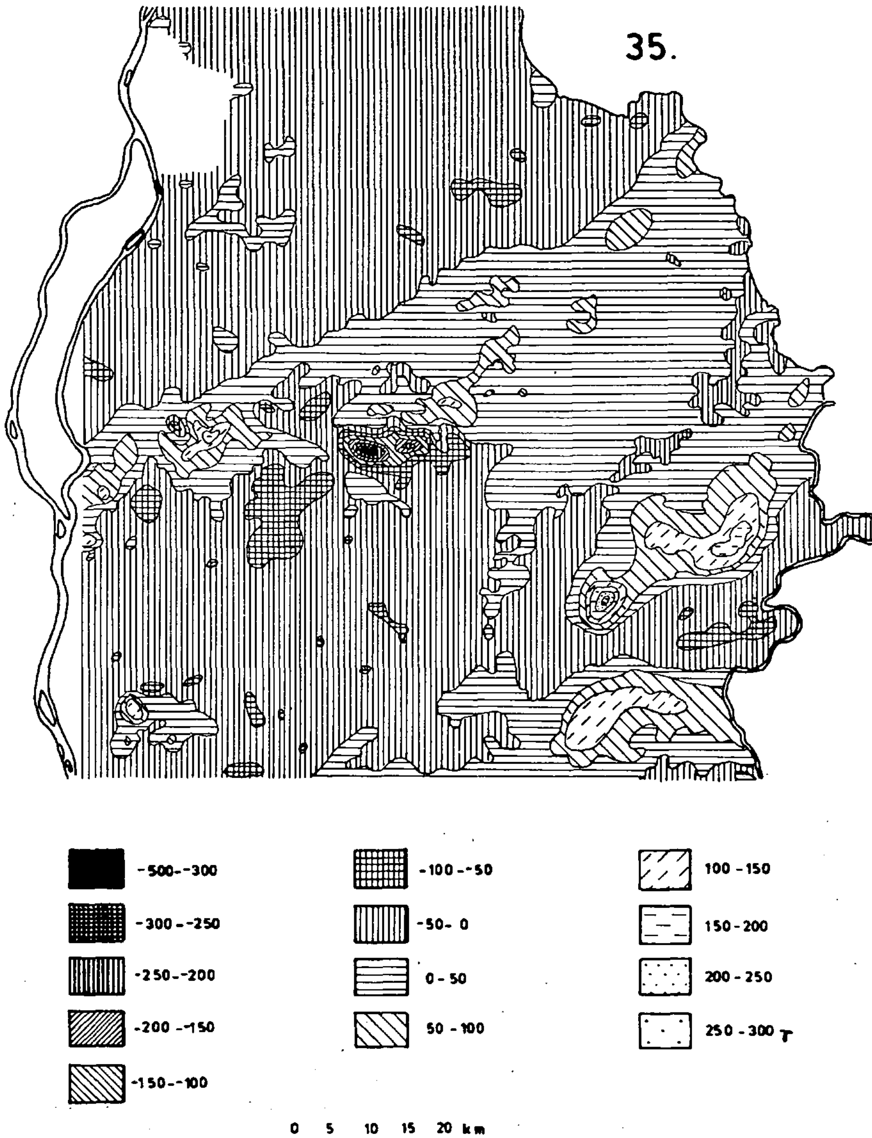


Fig. 35. Geomagnetic map of northern part of region between the Danube and the Tisza (ELGI)

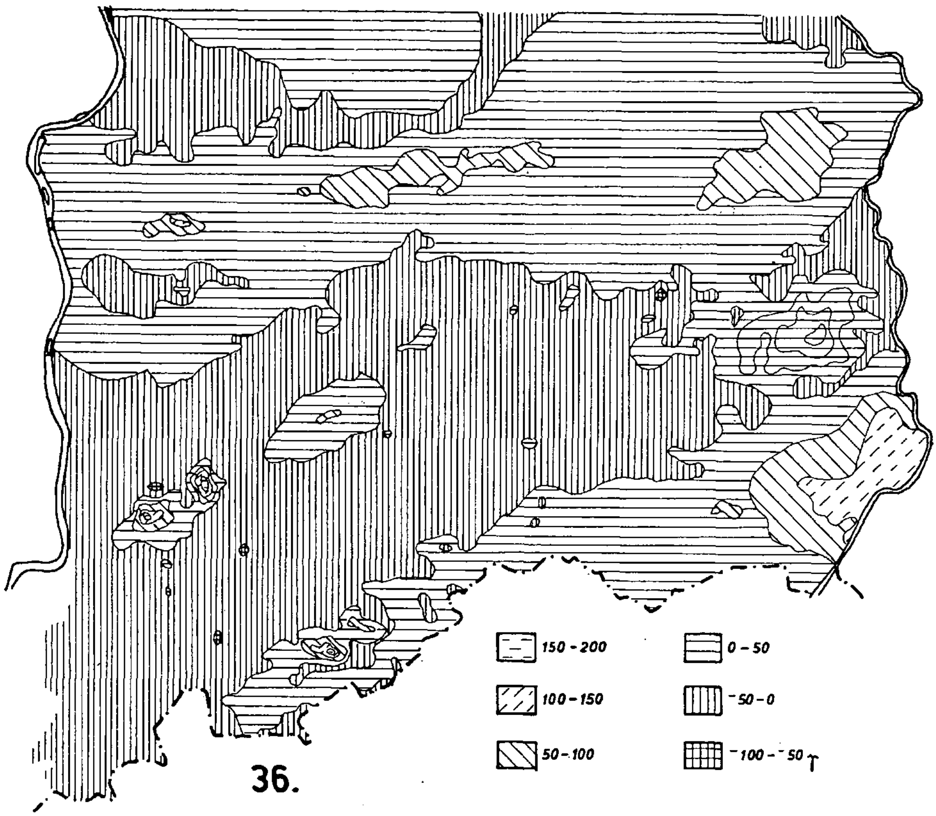


Fig. 36. Geomagnetic map of southern part of region between the Danube and the Tisza (ELGI)

gations of MOLNÁR. These indicated that, on proceeding south-eastwards in this region, there is a strong increase in the layer thickness of the aeolian sand, and the surface of the sand talus originating from the Danube at the end of the Pleistocene and in the Holocene can be traced at increasingly greater depths.

However, our hypothesis is also supported by the primeval hydrographic map of the southern part of the region between the Danube and the Tisza (Map 8). This demonstrates that the swamp zones in the alluvial area of the Danube were situated on the eastern edges of the potamogenic plain (i.e. the edges distant from the river), and hence conformed to the eastward-tending terrain and subsidence sloping characteristic of the whole of the region between the rivers; at the same time, the same types of swamp zones accompany the Tisza, in direct contact with it on the right-hand (western) side, while those on the left-hand side lie fairly distant from the river.

In this light, of course, the question arises as to whether the surface elevation in the area of Felgyő (as interpreted from the satellite photographs; see Chapter 4) really is an elevation, or whether the Tisza is diverted to the south-east by a possible surface depression of the large southern subsidence trough beginning at Csongrád.

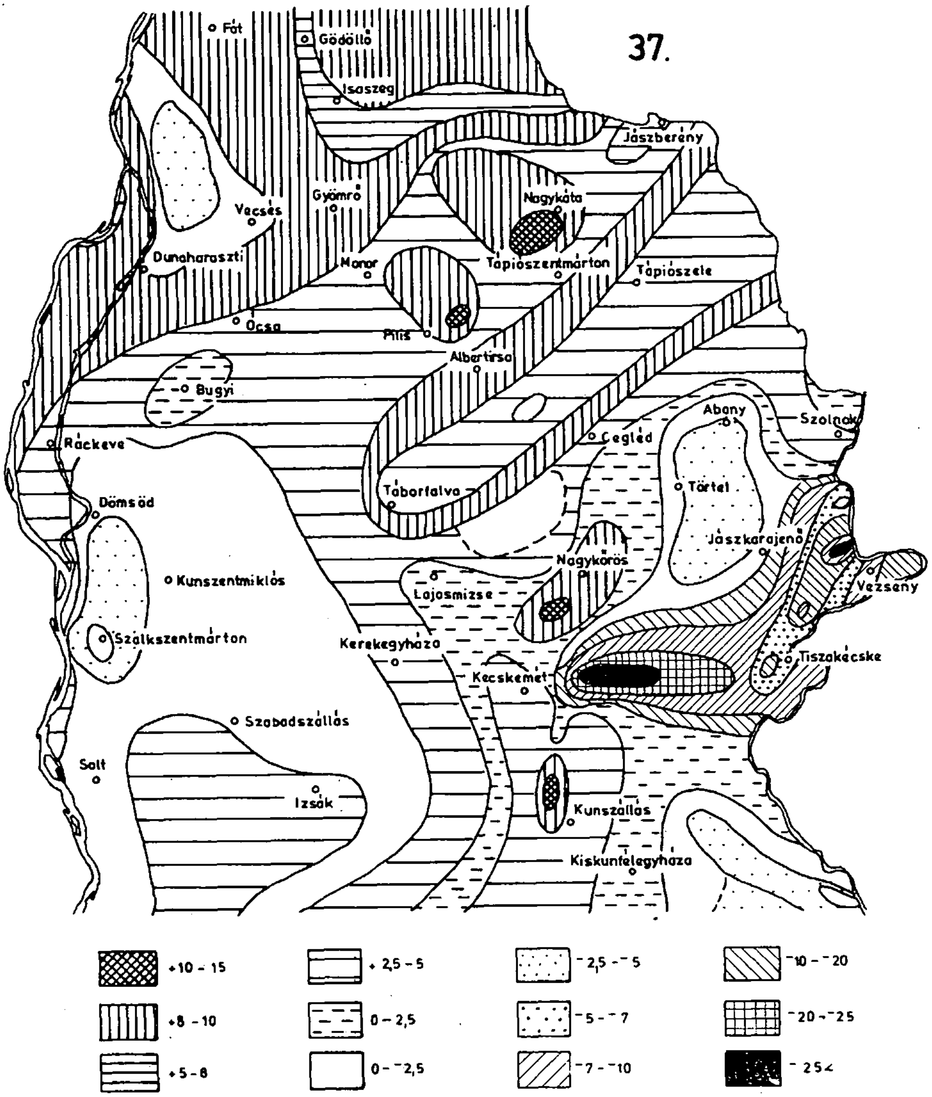


Fig. 37. Geokinetic map of northern part of region between the Danube and the Tisza (BENDEFY)

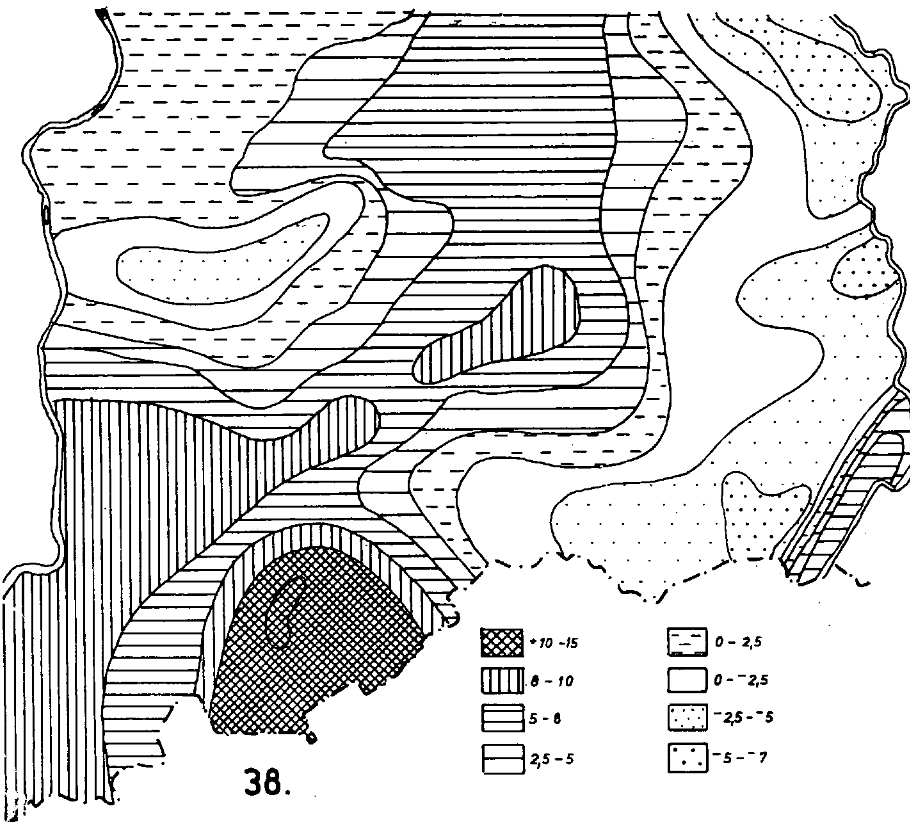


Fig. 38. Geokinetic map of southern part of region between the Danube and the Tisza (BENDEFY)

The facts already referred to clearly support the view that the elevated relief situation of the *Illancs drift sand zone* and the *loess table-land* that developed in the southern half of the region between the Danube and the Tisza is not merely a particular result of the accumulation; it is rather a geotectonic consequence reflecting the permanent geokinetic tendencies of the accumulation. Thus, it is by no means accidental that the areas with the greatest relief energies and situated highest above sea-level coincide exactly with the highest structural domes (see Maps 31 and 32) and at the same time with the gravitational maxima (see Map 34). In the district of Illancs, for example, where the height above sea-level is 174 m, the large maximum between Érsekcsanád and Rém in the gravitational map is found virtually in a bed situation. However, the geomagnetic map (Map 36) similarly shows a maximum in the same section, and maximum zones also indicated by our relief energy map (Map 4). That is, the mutually supporting indications here point to a young and rapid elevation. Further agreeing information is provided by the geokinetic map (Map 38), since this suggests a strong, recent elevation of the surface in this area.

Here, therefore, the satellite information is very strongly supported by our

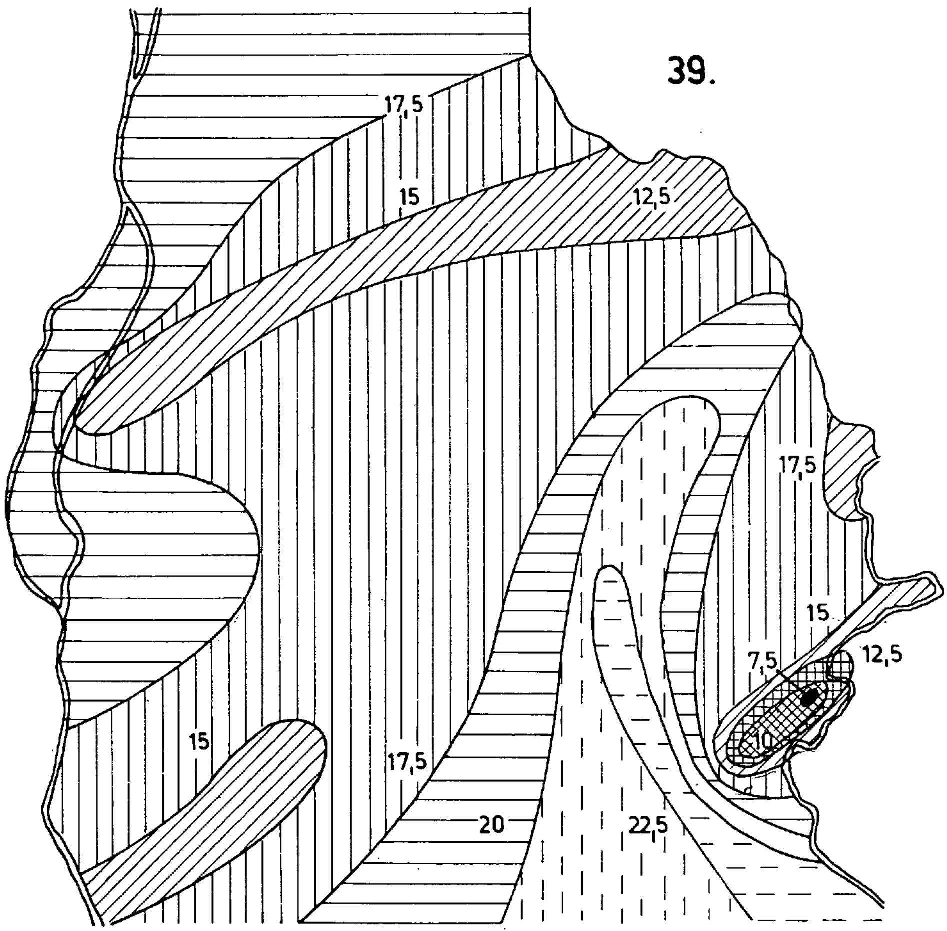


Fig. 39. Geothermal gradient data on the northern part of the region between the Danube and the Tisza (BOLDIZSÁR, 1962)

deep-geological data, so that it appears possibly *worthwhile to carry out further research in the future into the deeper causes of the correspondences.*

The agreement between the surface and the maps of the depth and geophysical conditions is almost just as characteristic and striking in the area of *Katymár-Madaras*. Here too the relief map (Map 2) and the relief energy map (Map 4) accentuate a local surface specification, the position of this coinciding exactly with a strongly emphasized local maximum in all of the geophysical (geokinetic, gravitational and geomagnetic) and dynamic (substratum, Lower and Upper Pannonian bed relief) maps.

All of the geoscientific maps reflecting the relief conditions of the substratum and the Tertiary layers deposited on it bear witness that the region between the Danube and the Tisza is divided orographically into deep-lying ranges, running parallel to one another, and with axes corresponding to the main strike direction

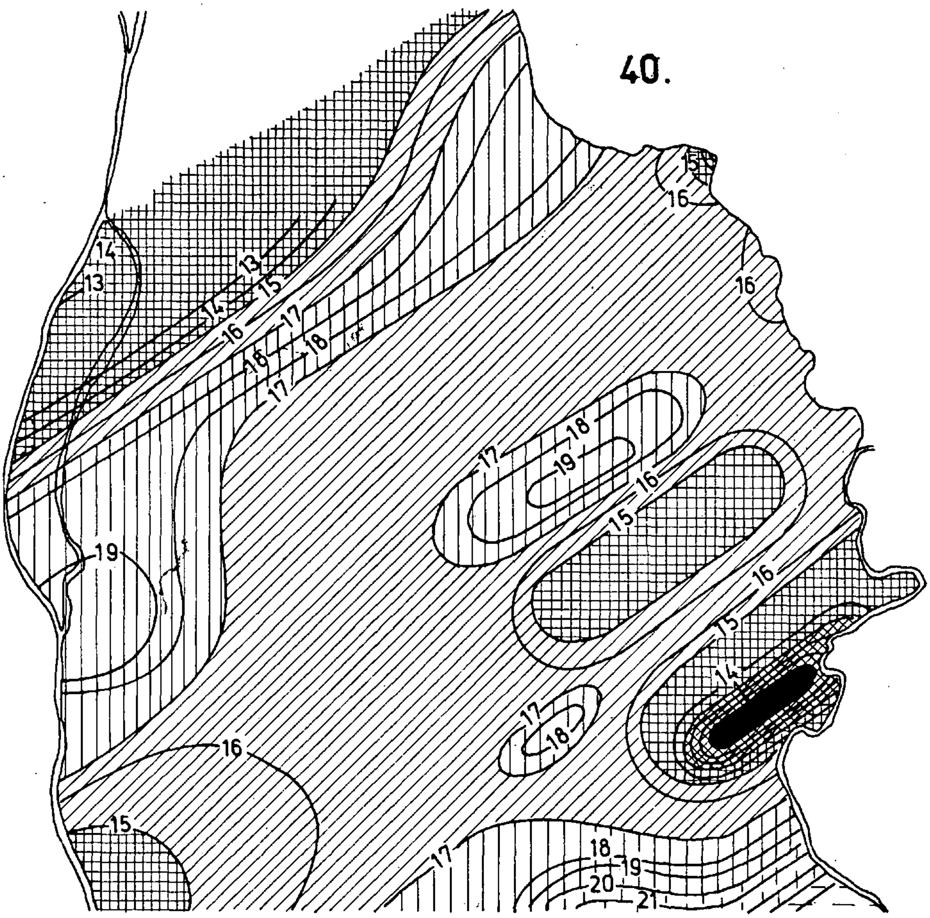


Fig. 40. Geothermal gradient data on northern part of region between the Danube and the Tisza (URBANCSEK, 1963)

(SW-NE) of the middle hills. In the southern half of the region between the Danube and the Tisza, however, this SW-NE sectional structure is reflected even on the surface through some phenomena. For example, the geomorphologic, geologic and hydrographic area-dividing boundary of very high relief energy and step height between Sükösd and Hajós is undoubtedly causally connected with the deep-lying structural line on the gravitational and the substratum and Pannonian bed maps which delineates from the north-west the upthrust with the axis Érsekcsanád-Kéleshalom.

The facies boundary showing up clearly between Baja and Jánoshalma in the geological map (Map 12) and in the satellite pictures is a straight line that separates sharply areas of loessy and of drift sand petrology; in our view, this boundary can similarly be brought into correlation with the deep-structural and kinetic characteristics of the area. A very strong reason for this is that the aeolian process itself would

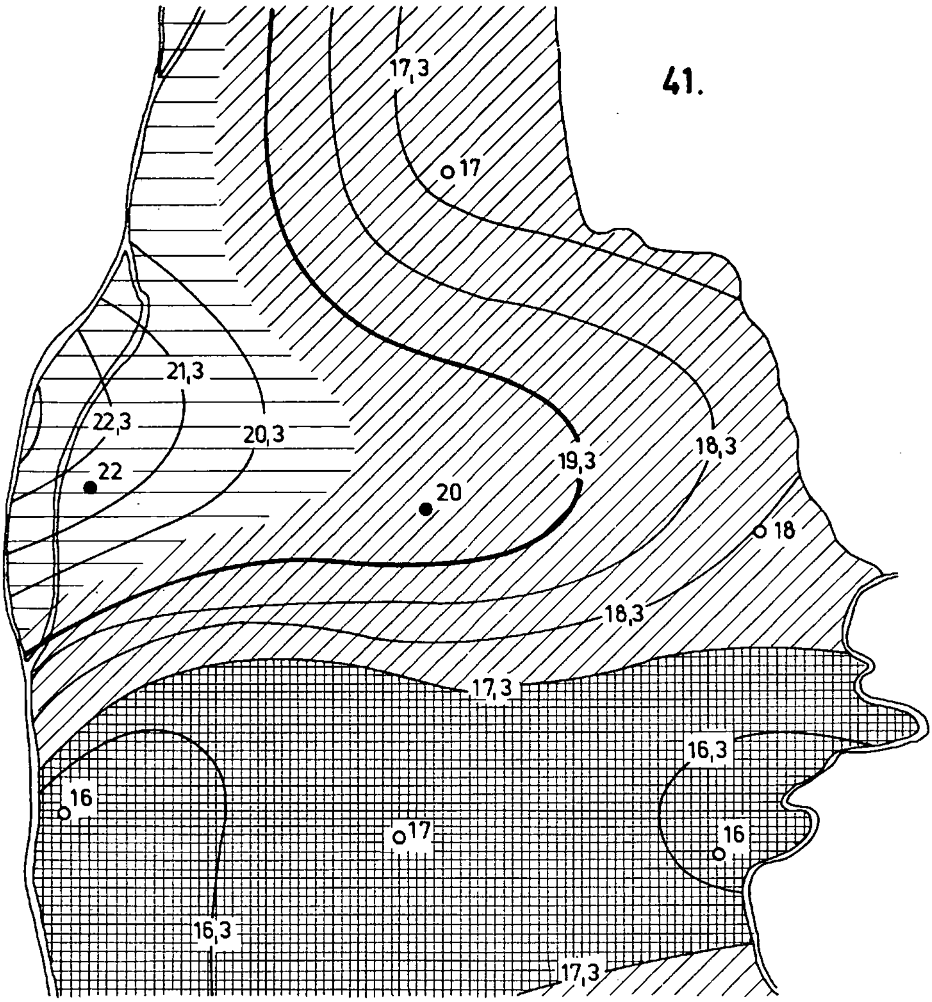


Fig. 41. Geothermal gradient data on northern part of region between the Danube and the Tisza (BENDEFY, 1965)

have been unable to accentuate such SW-NE strike lines on this area of aeolian sedimentaion, as the aeolically elevated bands here and elsewhere throughout the entire region between the Danube and the Tisza are all perpendicular to this: they all exhibit NW-SE directions.

Another striking phenomenon, that can likewise not be brought into accordance with the deflative and accumulative landscape-forming tendencies of the predominant winds, is that valleys with an east-west axis can be observed in the district of Katymár-Madaras in the satellite pictures (squares FG/9 in photograph no. 19). However, these lineaments are not artificial and are not of modern origin; they are also found on the primeval hydrographic and the relief maps. The fact that their direction is

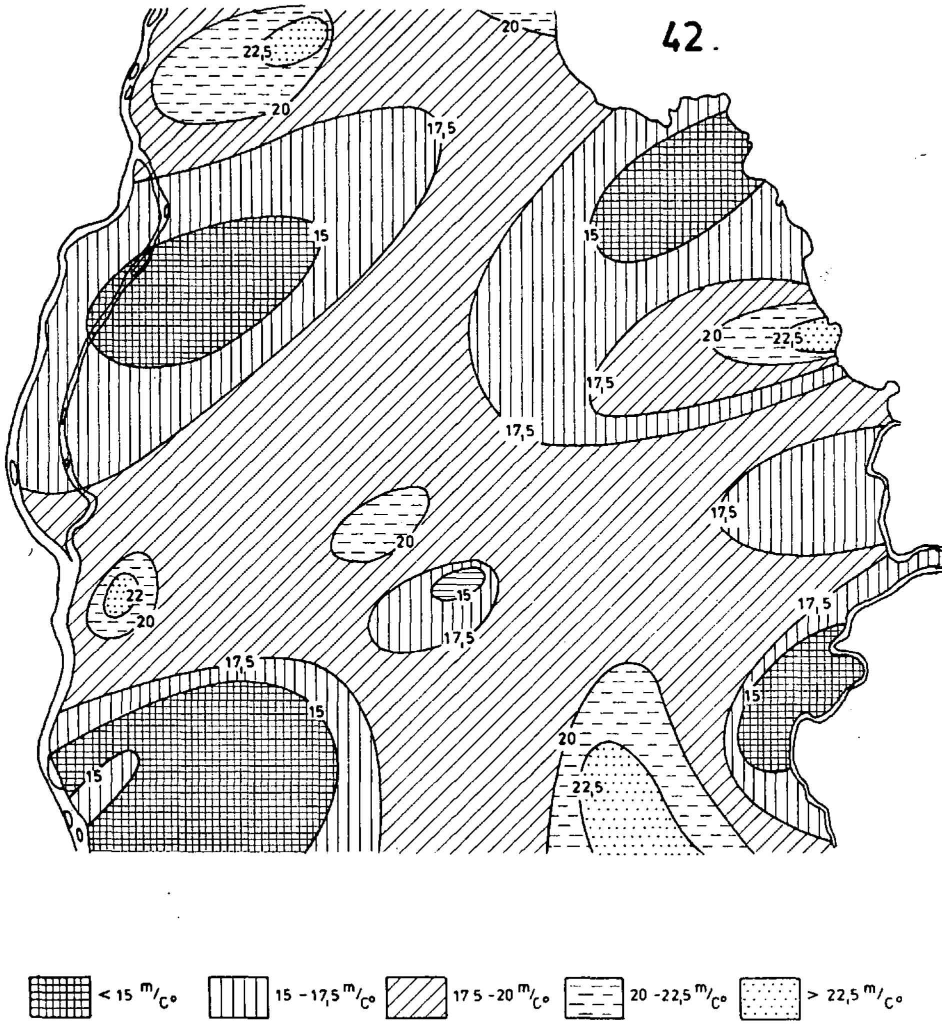


Fig. 42. Geothermal gradient map of northern part of region between the Danube and the Tisza (JAKUCS; JATE)

exactly the opposite of the general regional morphogenetic tendencies probably means the emphasized manifestation of the tectonic preformation here too.

In particular the relief maps of the basin floor (Maps 29 and 30) and the Lower Pannonian bed map (Map 31) strongly highlight the NW-SE directional structural zones of the southern half of the region between the Danube and the Tisza. These by and large mutually parallel structural bands have produced a stepwise system of levels of various depths in the situation of the deep layers. On proceeding from the south-west towards the north-east, there is generally a stepwise increase in the depths of the different Mesozoic and Tertiary surfaces. Structurally, therefore, the whole region is

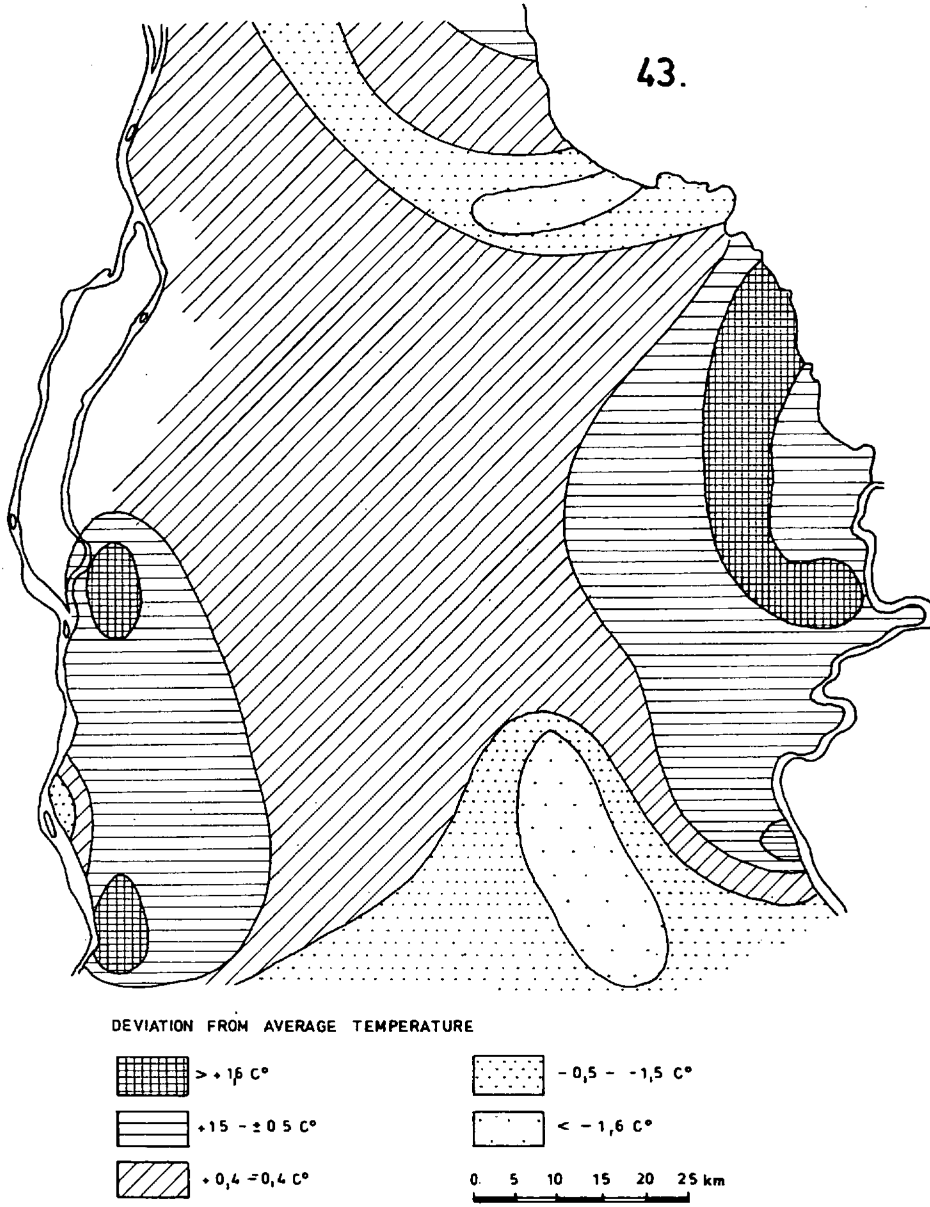


Fig. 43. Geothermal anomaly map of northern part of region between the Danube and the Tisza (STEGENA)

divided up virtually in a chessboard pattern into the main and the transverse substratum directions; we thus have every reason to assume multiply renewed structural sections between the individual steps throughout the entire Tertiary and Quaternary ages.

It should be noted in passing that the expressions "structural lines" and "structural sections" are deliberately used instead of "break lines" and "plicated dislocation zones". The reason for this is that our experience to date indicates that it would be very difficult to de ide definitely whether we really are concerned here with a break structure, or whether (at least in part) these are plication movement processes of an upthrust and synclinal nature.

As has already been mentioned, the large-structural picture of the whole region shows a chess-table-like pattern, and undoubtedly favours the hypothesis of fault lines and a break structure. At the same time, however, the upthrust forms are manifested almost everywhere is the small structures. Thus, in the maxima at Algyő, Üllés, Szank, etc., besides the breaks a primary role is definitely played in the development of the structure by the stratal bending stress. The simultaneous and syngenetic connections of these two types of movement processes can probably be reckoned with, therefore.

A comparison of the Lower and Upper Pannonian bed maps (Maps 31 and 32) in particular proves that in the course of the Tertiary and the Quaternary the tectonic steps of these areas did indeed subside, with differing dynamics, but permanently. The extent of the subsidence of the concrete surface in unit time was generally the greater, the closer the area in question lay to the section of the Tisza valley between Csongrád and Hódmezővásárhely. Thus, whereas the extent of the Intrapannonian subsidence can scarcely be detected in the district of Madaras in the south-west band, the movement resulted in a difference in level of more than 1500 m along the line Algyő-Szank.

As also supported by the detailed investigations by MOLNÁR, the very considerable thickness of the Pleistocene and Holocene strata in the Tisza valley demonstrates that the regional differences in the dynamism of the subsidence (which were of the same order of magnitude) remained characteristic throughout the Quaternary too.

In the light of the deep-geological information, therefore, the main structural features of the southern part of the region between the Danube and the Tisza might be summarized in that large, sediment-collecting, independent geosynclines can not be found here. In contrast with this, however, the eastern half of the region is to be interpreted as an extended wing (rising towards the west) of the large sediment-collecting basin in the area Csongrád-Hódmezővásárhely-Szentes. The western part of the region is characterized primarily by the presence of maxima in the (high) upthrust situation.

Accordingly, it emerges clearly that if we try to evaluate these structural features from the aspect of hydrocarbon accumulation and research, it must logically be concluded that the highly elevated maxima in the south-western part of the region between the Danube and the Tisza do appear structurally suitable for the storage of hydrocarbon; nevertheless, they probably possess such inextensive and narrow accompanying sediment-collecting synclines that their order of magnitude did not permit the most favourable situations as regards the possibilities of formation and accumulation of hydrocarbon in the Intrapannonian. Hence, even if hydrocarbon is found in this area, its quantity is hardly likely to be substantial.

Fig. 44. Known areas of hydrocarbon occurrence between the Danube and the Tisza (KŐRÖSSY—FEHÉR)

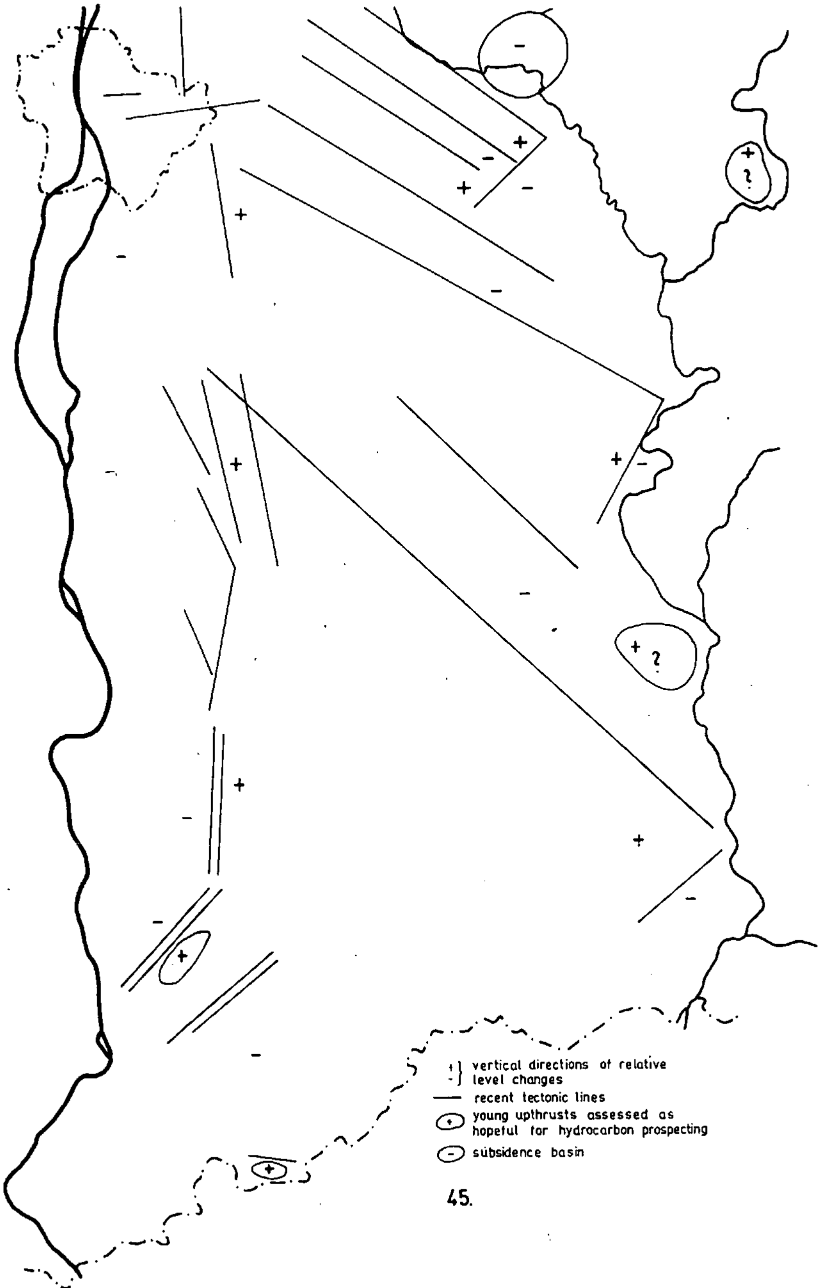


Fig. 45. Young structural phenomena and further areas assessed as hopeful for hydrocarbon research in region between the Danube and the Tisza; derived from a complex geoscientific interpretation of satellite information (JAKUCS; JATE)

The question remains, however, of whether a Prepannonian petrology for hydrocarbon development existed in this region. As regards this possibility, we would not discount the districts of Illancs and Katymár-Madaras as possible prospecting areas (see Map 45).

The situation is completely different in the area lying towards the Tisza valley from the structural line Kiskunhalas-Pusztamérges-Mórahalom, which is a very extensive Pannonian basin-wing. From the aspect of hydrocarbon storage, any smaller "parasite dome structures" in this wing (the maxima at Szank, Üllés and Algyő, and that we discovered between Forráskút and Balástya in 1968) have essentially more favourable positions and possibilities than the previoushighly-situated maxima. The reason is that they may have become the catches for the considerable hydrocarbon migration that may be assumed from the direction of the centre of the Tisza valley Pannonian geosyncline containing thick structures with great area.

In Map 44, which is a revised variant of the map of KŐRÖSSY, we present the hitherto known hydrocarbon-bearing structures in the region between the Danube and the Tisza, and also the assumed regional zones of hydrocarbon accumulation. Map 45 depicts in a combined form the young structural phenomena we have identified by complex geoscientific integration of the satellite information, together with the further districts regarded as hopeful from the point of view of hydrocarbon prospecting.

Finally, special emphasis should be laid on the circumstance that in most cases the conclusions arising from the interpretation of the surface conditions in the *northern half* of the region between the Danube and the Tisza are in virtually complete contradiction with the phenomena reflected from the deep structure. The main strike directions of the relief and the surface geological conformations correspond quite clearly to the transverse directions of the middle hills, i.e. they give NW-SE range systems. In contrast with this, however, the essence of both the arrangements of the gravitational and the geomagnetic field forces (Maps 33 and 35) and the oval strips of the geothermal gradient map (Map 42) is that longitudinal structures with a SW-NE strike have developed consequently in them. The deep-structural zones (longitudinal subsidence troughs and intermediate table-lands), therefore, are in harmony with the main range directions of the middle hills in the northern part of the region between the Danube and the Tisza; they are usually perpendicular to the directions of the surface landscape structure, but if not then at any event they intersect these directions.

This circumstance is all the more noteworthy for the main strike directions of the isoclinic lines in the recent geokinetic map of BENDEFY (Map 37) correspond to the deep-lying strikes; this means, therefore, that *although the permanent tectonic tendencies of the region are manifested here too and at present too in the tendency of the surface development, these factors are obscured so as to be unrecognizable and unevaluable by the stronger processing factors recently forming the surface.*

In the northern half of the region in question, there is only a single band where the tectonic conclusions of the satellite interpretation are perhaps supported by the map data relating to the deep structure. This site is the Pest basin, the eastern boundary of which was explained by the signs of tectonism with a north-south strike, this not being in contradiction with the information from the depths. This connection, however, is of such local significance that it must clearly be seen that *the tectonic con-*

sequences deduced from the satellite photographs received essentially no worthwhile deep-structural support in the northern half of the region.

It follows from all this, however, that the fundamental features of the deep-lying conditions can not be compared causally with the determinant dynamo-geographic characteristics of the surface morphological state in the northern part of the region between the Danube and the Tisza. This means that the areal analyses of the satellite photographs reflecting the peculiar surface conditions of the research region are not able either to detract from or to support the arguments confirmed by the traditional deep-research channels (for example, hydrocarbon prospecting) in the northern, hilly half of the region.

In conclusion, if we now wish to summarize the general consequences of these perceptions, the result is rather a surprising one: *the geoscientific interpretation of remote sensing may be more informative on completely plain landscapes than on hilly landscapes covered with young sediments, where the erosional directions (proto-sequences) imposed by the greater relief may obscure the weak features of the landscape dynamism (strato- and tectosequences) projected from the deep structure.*

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ЕСТЕСТВЕННЫЕ ГЕОГРАФИЧЕСКИЕ ОСНОВЫ СОЛОНЦЕВАНИЯ НА БОЛЬШОЙ НИЗМЕННОСТИ

М. АНДО

Введение

Солончаковые почвы и солончаковые озёра на Большой мизменности находятся, главным образом, между Дунаем и Тисой, а также на отложениях, созданных их притоками. В то время, как в системе насоса (в частности, между Дунаем и Тисой) аккумулировался осадок, содержащий много карбоната кальция, в осадке, созданном Тисой (большей частью, на кислых осадках, состоящих из вулканических извержений) произощёл процесс солонцевания с различным химическим содержанием. С одной стороны, в системе осадка двоякого происхождения находятся солончак, известково-содовые солончаковые почвы, с другсй стороны солонец, т. е. почвы типа солодя (рис. 1.). Поверхность обеих солончаковых почв, в некоторых местах, покрывает так называемая аморфная кремнєвая кислота. Поэтому их поверхность голая и цвета похожи. Разница между ними, однако, в том, что если на поверхности солончаковой почвы самссадка соды, и это часто бывает, то в случае солонцеватой почвы этого никогда не бывает. Сабо (1861) уже больше ста лет назад установил эту существенную разницу. В солонцовой почве типа солончака, известь и сода находится во всём сечении, а в почве типа солонца только в слое В и С. Для последнего типа почвы характерно, что под уровнем вышелачивания создались лимонитовые железные конкреции щариковой формы, и что сулъфаты накапливаются внизу слоя В, т. е. под карбонатным слоем, и часто встречаются кристаллы гипса. (Трейц 1924, Арань 1956, Саболч 1961). Два типа солончаковсй почвы подобны в тсм, что в их адсорбционных комплексах значение S 10—12% натрия. Отдельные типы, классификация которых основанна на принципе генєтики, была сделана Саболчем (1954), можно классифицировать и по их растительным покровам. Принимая во внимание классификацию почвы Шигмонда, Мадяр (1930) указал на такие взаимозависимости. Определение классификации почвы, основанное на современной генетической основе, при помощи голофильных растительных ассоциаций, т. е. синеколгическую систематизацию объединений индикационного характера, произвёл Бодрогкёзи (1962, 1965).

Спєциалисты более молодого поколения (Мате 1956, Саболч 1961), изучающие солонцевание, повторно подчеркнули то установление классиков исследования (Шигмонд 1923, Трейц 1924), что солонцевание, независимо от возникшего типа, произошло в периодически покрытых водой, т. е. насыщенных водой почвах. При освещении вопроса дальнейшим шагом вперёд было осознание роли биологических процессов, происходяших в почве. Муракёзи в своей книге, изданной уже в 1902 г., причины солонцования объясняет биологическими процессами, происходящими в болотах. Это оригинальное правильное представ-

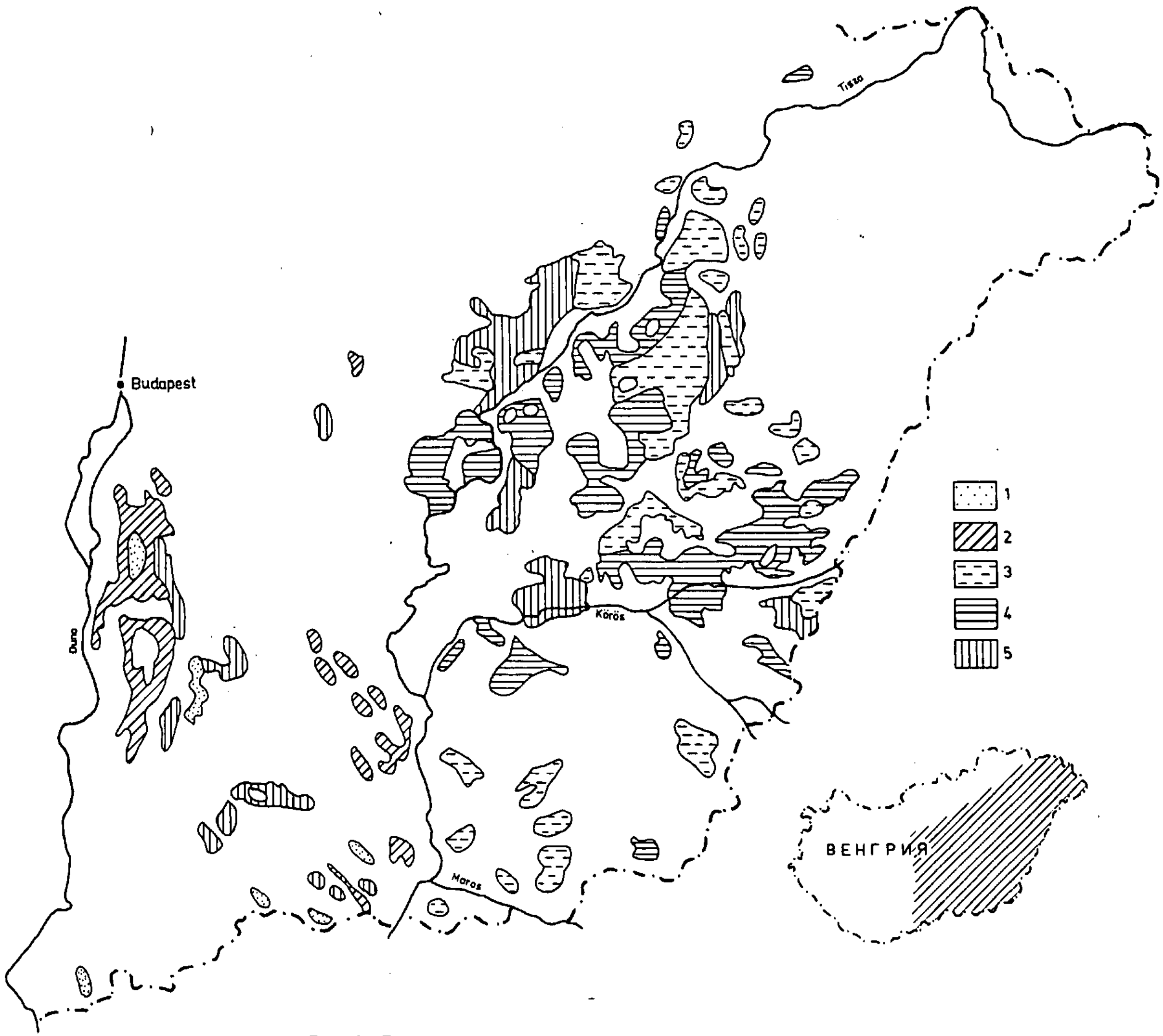

Рис. 1. Солончаковые территории Большой Низменности
1: солончак; 2: солончак-солонец; 3: луговой солонец; 4: лесостепной луговой солонец;
5: солонцевая луговая почва

ление, однако, не соответствовало установлениям Хилгарда (1894), изложенным в его книге, которая переведена и на венгерский язык, поэтому оно отодвинулось на задний план. Хилгард образование соды считал результатом неорганических химических процессов. По ему мнению сода образуется в силу взаимодействия карбоната кальция и натриевой соли (поваренная соль, грауберова соль), которые находятся в почве. Тот факт, что сода не может возникать таким путём, Янош Ирини (1839) доказал уже гораздо раньше до рождения Хилгарда (Арань 1956), Гедроиц (1926) образование соды объясняет гидролитическим разложением комплексов натрия. По ему мнению, сода создаётся из натрия, адсорбированного на коллоидных частицах под влиянием углекислоты. Последняя теория связана уже с кругообращением углерода, т. е. биологическими процессами. Выше упомянутые теории, однако, недостаточны как для приемлемого объяснения образования соды, так и образования солончаковых почв (Вамош 1955, Арань 1956, Ковда 1964).

Шигмонд (1923) считал причиной солонцевания аридный климат, периодическое покрытие водой и гидроизоляционный слой почвы. По его мнению солонцевание всегда имеет место при присутствии упомянутых трёх факторов. Трейц (1924) в своей книге кроме этих факторов подчеркнул и значение биологических процессов и поставил задачу изучения происходящих в иле и воде микробиологических процессов, главным образом, изучения кругообращения серы и натрия. Трейц уже в начале этого века говорил о значении редукции сульфата, ведшего к образованию соды. Что касается кругообращения азорая, он установил возможность образования соды в результате реакции карбоната аммония и натриевых солей. В сущности, кроме признания процесса образования соды в почве Лебланка и Солваи, как и Гедроик, он тоже сослался на возможность образования соды при взаимодействии глиняных коллоидов натриевого содержания и углекислоты. Значение преобразования сернистых соединений в образовании солонцевания, позже всё больше признают и другие (Хермзен 1954, Штаркеи 1950, Йонеда 1964 и т. д.).

На нашей Низменности и в наши дни существуют солончаковые озера и болот большой пртяженности и есть такие территории, которые осущаются только в середине лета, а потому имеется возможность изучения процессов и изменений, которые происходят при водно-сухом периодах. Кроме того, на обеих территориях ведётся значительное выращивание риса и разведение рыб, и изучение проблем, возникающих в этих обеих отраслях хозяйства, а именно болезней растений и рыб почвенного происхождения (напр. гибель корней риса и массовой гибели рыбы в силу сероводорода и аммиака) вызвало необходимость признания изменений, происходящих на временно покрытых водой территориях, что в итоге означало исследование составных процессов солонцевания.

Изменения в почвах, покрытых водой

В залитых или насышенных водой почвах весной, с повышением температуры начинается разложение органических веществ. При оптимальных условиях бактерии размножаются, их число увеличивается в несколько сот раз, и даже выше, чем в тысячу. Главные факторы их размножения: количество разлагающегося органического вещества, его качество и температура. По нашим исследованиям и опытам, обильный запас почвы в неорганическом и органическом азоте, также является фактором размножения бактерий. При благоприятных условиях рахмножение аэробных бактерий в логарифмической фазе сопровождается более обильным расходованием кислорода. С исчезновением кислорода начинается редукция нитрата, а потом почти одновременно с ней начинается редукция марганца и железа, которая позже, при более низком редоксипотенциале сопровождается редукцией сульфата и фосфора (Поннамперума 1955, Вамош 1955, Токаи 1956). Так как раствор почвы содержит только несколько миллиграммов иона нитрата и фосфата, возникающие в почве изменения могут быть прежде всего результатом превращения обильного ионов сульфата и серы.

Изменения значения pH и редоксипотенциала (Eh_o), а также Fe^2+ и Mn^2+ в иле и воде рыбного водоёма, содержащего известь, и рисового поля, находящегося на кислом луговом солонце изображены на рис. 2 и 3. Редуктивные процессы связаны с разложением органического вещества. Электроны, образующиеся при бактериальном дыхании превращают восстановляемые окиси марганца и железа как рецепторы в ионы Mn^{2+} и Fe^{2+}. В анаэробных условиях органические вещества почвы и растительные остатки разлагаются с образованием органической кислоты и газа. Большое количество газа — метан и только меньшее количество — углерод, азот и водород. Жирные кислоты с короткими цепями, возникающие в ходе бродильного разложения используют не только восстановительные бактерии, но и бактерии метана. Под влиянием Eh $_o$mv начинается сильная редукция сульфата, ниже к которой энергию отчасти обеспечивает сжигание водорода, проведённое Клостридиумами. Источником энергии востановителей сульфата может быть ещё этанол, молочная кислота, пивовиноградная кислота, но использовать ускусную кислоту они неспособны. Кроме использования водорода, восстановительные бактерии сульфата требуют ещё и органических соединений как источника углерода (Штаркей 1966).

Самое общее выражение редукции сульфата следующее:

$$Na_2SO_4 + 4H_2 \xrightarrow{H_2O} NaSH + NaOH + 4H_2O$$

$$NaSH + H_2CO_3 \longrightarrow NaHCO_3 + H_2S$$

Значит, в врезультате редукции сульфата возникает бикарбонат натрия и водород. В результате вышесказанных процессов значение pH слоя воды ворастает, а ил вследствие бактериальных действий остаётся нейтральным. H_2S с ионами Fe^2, находящимися в почве, а также некоторыми соединениями железа образует FeS. По нашим исследованиям в приблизительно нейтральном иле бактериальные редуктивные процессы являются сильными и тогда, когда в слое воды, pH которой выше 9,0, число бактерий вледствие щелочности уменьшалось до минимального.

Большое уменьшение в воде бактерий, по нашему мнению, является следствием не только увеличения числа ионов OH, а может быть и следствием токсического влияния так называемого свободного аммония. Как установлено нами, неблагоприятное влияние свободного аммония проявляется и в отношении живущих в воде синих водорослей. Вследствие гибели во время цветения воды водорослей и тин, т. е. вледствие дезаминоза их разлагающихся белков, количество свободного аммония и свободной может увеличиться. Вследствие таксикации аммония, как мы это наблюдали в течение долгих лет, в отдельных солончаковых озёрах нет рыбы. В этой стадии в иле верхнюю границу восстановительного слоя обеспечивает не потребление кислорода организмов аэробного слоя, толщина которого обычно несколько миллиметров, а окисление восстановительных веществ. Главным образом, в результате окисления сульфида железа повехность прблизительно нейтрального ила от окисы железа получает характерный залёно-коричневый цвет.

Количество сульфида ила в иле кислой почвы больше. Оно может достигать и 40—50% миллиграммов, а в известковой почве оно меньше 10% мг. Позже повышение уровня восстановления останавливается, а потом очень медленно падает. Там, где в до сих пор в восстановительном слое ила условия стали более аэробными, FeS окисляется.

$$FeS + 2O_2 = FeSO_4$$

Полученный сульфат (II) железа гидролизирует, вседствие чего образуется серная кислота и гидроксид железа:

$$FeSO_4 + 2H_2O = Fe(OH)_2 + H_2SO_4$$

H_2SO_4 из своего окружения освобождает H_2S,

$$Fe + H_2SO_4 + FeSO_4 + H_2S$$

которое может дальше окисляться до образования элементарной серы.

$$2H_2S + O_2 = H_2S + 2S$$

Простое уравнение окисления серы, состоящего из нескольких ступеней, может быть записано следующим образом:

$$2S + 3O_2 + 2H_2O = 2H_2SO_4$$

В микробиологическом окислении элементарной серы сульфатов и тиосульфатов могут действовать, главным образом, бациллы Тиба (Thibacillus genus).

Это изменение, т. е. окисление сероводорода может возникать, с одной стороны во время покрытия водой, с другой при испарении или спуске воды.

Значит, во время покрытия водой в иле осуществляются восстоновительные процессы, а во время сухого периода при аэрбных условиях приведённые соединения окисляются. Однако, окисление в иле может начинаться ещё до осушивания или спуска воды, так, например, если с резким похолоданием слоя воды, количество кислорода увеличивается и вседствие этого поверхностный слой ила может окисляться.

В воде озер, однако, освобождение H_2S обычно начинается во время осеннего похолодания. Бывает, что этот процесс из-за неожиданно наступающей зимы происходит под ледяным покровом. Так как в таких случаях H_2S не могло удалиться в воздух, потому что слой воды не мог соприкасаться с атмосферой, окисление H_2S затянутое или вообще не происходит. Происходящее таким образом увеличение H_2S во многих случаях может вызвать полную гибель рыбы, например, в мёртвом рукаве Тисы, в озере Палич и в озерах Тата.

Итак, в процессе солонцевания, образования соды основным условием рассмотренного выше окислительно-восстановительного процесса является временное покрытие водой, т. е. водносухой период. Это предположение подтверждают факторы Шигмонда. В иле и воде почв, залитых водой, как мы видели, происходят одинаковые или приблизительно одинаковые процессы. Несмотря на одинаковые процессы, всё-таки возникли солончаковые почвы с неодинаковыми свойствами, которые характеризуются количественными различиями, т. е. пропорциями соединений в горизонте A и B. Из того, что на такой сравнительно маленькой территории, как Большая низменность и на её частях, находящихся на территориях соседних стран, под одинаковым влиянием климата возникли совсем отличные друг от друга солончаковые почвы, мы могли сделать вывод, что минеральный состав первоначальных наносов рек, т. е. содержание в нём извести могли влиять на действия вышеупомянутых процессов, которые создали солончаковые почвы и их многочисленные переходные виды.

Сложный процесс распространения солончаковых почв мы можем объяснить химическими процессами, происходящими в почве и в конечном счете приводящими к солонцеванию, только тогда, если не теряем из виду, что носитель и движущая сила этого процесса по существу — вода, прчем как и грунтовая, так и оросительная вода. Между ними, однако, в большинстве случаев имеет место взаимовлияние. Вследствие орошения зеркало грунтовой воды поднимается. Если это достигает такой высокой степени, что грунтовая вода поднимается близко к самой поверхности почвы и капиллярным путем может подниматься, вследствие испарения и движения поднимающегося раствора, в верхних слоях почвы могут накопляться соли, что неизбежно ведет к солонцеванию почвы. Также опасным является и то, что орошают такими водами, в которых количество солей — в том числе натриевой соли — значительное, так как в таких случаях растворенные в воде соли накапляются на поверхности почвы, и раньше или позже происходит слонцевание почвы.

Таким упрощенным образом, ясно понятно, какие опасности угрожают почве на наших нименностях в случае орошения, и что является причиной этих опасностей. Ясно и то, что если при орошении наступает накопление соли, компенсировать его невозможно ни правильной агротехникой, ни сортовыми семенами, ни удобрением, ни другими правильными мероприятиями, более того, в случае солонцевания почвы и эти правильные мероприятия пропадут даром, т. е. станут бесполезными. Поэтому в таких природных условиях, которые господствуют на венгерской Низменности, из самых важных вопросов — изучить в какой степени, когда и почему возникает опасность солонцевания почвы в ходе развития орошения.

Насколько легко понять вышеупомянутую общую установку, настолько трудно определить на данном месте, в случае данного плана на какой глубине надо держать грунтовую воду, принимая во внимание различные отношения почв и грунтовых вод, их различную химическую и физическую природы, и, конечно, и климатические данные, местные условия и т. д.

Насколько легче определить качество оросительной воды, в отношении чего в нашей стране мы располагаем уже хорошо разработанным применяемыми нормами.

Почвы на Низменности деляется на три группы:

1. на которых можно орошать без опасности солонцевания (около 10—12%),
2. на которых можно орошать только при определенных условиях, при соблюдении которых солонцевание не наступит (около 75—80%),
3. на которых не предлагается орошать, где при сохранении данных условий вследствие орошения непременно наступает дальнейшее солонцевание (около 6—8%).

Иначе говоря, это значит, что больше, чем три четверти Низменности может быть условно орошаемо. Поэтому чрезвычайно важны предварительные исследования.

Самым важным вопросом условно орошаемой территории является общая глубина уровня грунтовой воды в почве.

Мы знаем, что одной из главных причин солонцевания на Низменности в той или иной степени является соляная грунтовая вода, которая поднимается на поверхность почвы, в результате чего почва станет солочаковой. Поэтому та глубина грунтовой воды, ниже которой этот процесс не может происходить, называется *критической глубиной.* Поскольку уровень воды в почва превышает критическую глубину, раньше или позже закономерно произойдет солонцавание почвы.

Если сравнивать солончаковые территории Низменности с территориальным расположением солончаковых грунтовых вод с большой концентрацией соли, между ними можно установить тесное соотношение. На основании этого факта и данных других многочисленных исследований, мы можем сказать, что непосредственным источником накопившихся в солончаковой почве солей, в большинстве случаев, является грунтовая вода. Поэтому одним из важнейших качественных показателей грунтовых вод с точки зрения солонцевания является количество растворенных в них солей. Чем больше содержание соли грунтовой воды, тем интенсивнее — при прочих одинаковых условиях — действие солонцевания.

В ходе солонцевания кроме накопления растворимых солей, следует учесть происходящие в почве химические процессы. Самый важный из них взаимовлияние между поступившими в почву и находящимися в растворе ионами натрия натриевых солей и твердыми фракциями почвы. В результате этого взаимовлияния находящиеся в растворе ионы натрия на поверхности коллоидных частиц почвы в ущерб ионам кальция связываются и изменив коллоид-химическое состояние почвы, ухудшают свойства водного баланса. В какой степени связываются поступившие в почву ионы натрия натриевых солей зависит от концентрации солей в растворе и в пределах этого пропорции содержания солей натрия. Поэтому другой важный качественный показатель вод — это % натрия, который выражает пропорцию солей натрия в общем содержании солей в мг/л воды в %. Так, например, если почва и первоначально солончаковая и более большем количестве содержит замещаемые ионы натрия, то связь ионов натрия требует большего процентного содержания натрия в растворе. Мы уже видели, что влияние солонцевания зависит от грунтовой воды и от глубины уровня грунтовой воды. Предпосылкой солонцующего влияния грунтовой воды является её непосредственное влияние на формирование почвы, поступление в почву принесенных грунтовой водой солей.

Уровень грунтовой воды, выше которого под влиянием грунтовой воды может наступать солонцевание в почве, называется *критическим уровнем* грунтовой воды.

Известно, что воды на нашей Земле, искючая осадки, содержат в раствареном виде большее или меньшее количество минеральных и органических солей. При орошении соли отчасти или полностью (в зависимости от метода) остаются в почве или удаляются, т. е. оказывают на почву химическое, физическое и физиологическое воздействия. Эти воздействия зависят от качества оросительной воды, т. е. от химического свойства растворенных составных частей и от количества использованной воды. Значит, возможность солонцевания вследствие орошения во многом зависит от химического характера используемой оросительной воды. В нашей стране это практически означает, что самые лучшие для орошения естественные воды — это воды наших рек (Дунай, Тиса, Кёрёш, Марош). См. рисунок...., который ясно изображает относительную бедность вод наших главных рек на Низменности раствареными веществами. (Тиса, Марош, Кёрёш)

Но иное положение, если орошают из водоёмов, каналов, где собирается ильмень, или буровых калодцев. Например, из канала Хортобадь-Беретьё, который построен для собирания и отведения ильменя солончаковых территорий Средне-затисайского края, а теперь используют его воды для орошения.

Вода водоемов мертвых рукавов и главных каналов для собирания внутренних вод, особенно летом, когда главный сезон орошения вследствие испарения и экстрагирования насыщается и её качество может ухудшаться. В таких случаях пропорция растворенных в воде солей кальция и магнезия, по отношению к натрию, с точки зрения орошения может изменяться неблагоприятно.

В естественных водах эта пропорция чаще всего около 3:1, а пропорция воды канала Хортобадь-Беретьё и других каналов водоемов подпочвенных вод составляет 1:1 или ещё хуже. В этом случае солонцевание под влиянием оросительной воды уже может иметь место. Чтобы избежать этой опасности, необходимо принимать во внимание химический состав воды упомянутых источников. Если качество оросительной воды не благоприятное, его улучшить добиванием естественной воды (физическое улучшение) или химическими веществами, например, гипсом (химическое улучшение).

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EINIGE FRAGEN DER MORPHOGENETISCHEN SYSTEMATISIERUNG VON KARST-DOLINEN

ILONA BÁRÁNY

In jeder Forschungsperiode galt es als ein besonders interessanter Themenkreis, die Entstehung und Entwicklung der grossen Oberflächenformen zu untersuchen. Unter den Oberflächenformen sind die Dolinen am augenfälligsten, die von den subarktischen Gebieten bis zu den Tropen überall vorkommen. Bei der Untersuchung der Dolinen stand die genetische Erklärung ihrer Entstehung immer im Mittelpunkt.

Am Anfang der Kastforschungen (J. Q. SHAWKINS 1869, C. DIENER 1886, J. CVIJIČ 1893) vertaten einige Forscher die Ansicht, die Dolinen seien durch Lösung entstanden doch wurde diese Auffassung in der wissenschaftlichen Öffentlichkeit in Ermangelung entsprechender Beweisdaten nie allgemein anerkannt. Vorherrschend war dagegenis der dolinengenetischen Forschung, die Entstehung dieser Oberflächenformen auf ihren Einsturz zurückzuführen (W. ZIPPE 1854, E. TIETZE 1873, F. KRAUS 1887, E. MOJSISOVICS 1880, W. v. LOZINSKY 1907 usw.).

Am Anfang des 20. Jahrhunderts vertraten wieder viele Wissenschaftler die sog. Lösungstheorie (M. LUGEON 1911, A. GRUND 1910, E. JEREMINE 1911). Ein progressiver Vetreter der vorhin erwähnten Ansicht war K. TERZAGHI (1913), der auf den biogenen Charakter der Karstenwicklung hinwies. Seine Forschungen übten später auf die Tätigkeit O. LEHMANNs eine Wirkung aus, der eine zeitgemässe Erklärung der Karstentwicklung ausarbeitete. Im Einverständnis mit TERZAGHI lehnte LEHMANN (1931) die grundsche Zyklustheorie der Dolinenentwicklung ab. Er wies darauf hin, dass für die Dolinen eine Klimavarienz charakteristisch sei, wobei er betonte, die sich klimabedingt ändernde Vegetation stelle eine wichtige Voraussetzung in der Bildung von Lösungsdolinen dar.

Nach der Summierung der verschiedenen Auffassungen wurden mehrere Versuche unternommen, die Dolinen auf genetischer grundlage zu klassifizieren. Vor allem muss man hier den Namen H. CRAMERs (1941) erwähnen, der bereits mehrere Dolinentypen unterschied: Einsturz-, Erdfälle-, Schwund-, Lösungs- und Schwemmlanddolinen. Sein System ist jedoch bestreitbar, da er bei der Entstehung der einzelnen Typen den verschiedenen genetischen Faktoren nicht das gleiche Gewicht beimass, bzw. im Falle der Schwemmlanddolinen das Endstadium und nicht etwa die Entstehungsgenetik in entscheidendem Masse in Betracht zog.

Von der Jahrhundertsmitte an sind die Direktiven von H. LEHMANN (1956) massgebend. Ausser der Betonung der Klimavarienz gilt es als ein bedeutendes Verdienst LEHMANNs und seiner Anhänger, dass sie den engen Zusammenhang zwischen dem CO_2-Gehalt der Bodenluft und der Karstkorrosion erkannten. In den

Karstforschungen unserer Tage — darunter auch in der Dolinenforschung — stellt es eine recht wichtige Aufgabe dar, die Herkunft des die Aggressivität des Lösungswassers erhöhenden CO_2,bzw. seine in der Korrosion gespielte Rolle zu untersuchen.

Auch in internationaler Relation beschäftigen sich viele Forscher mit der Entstehung und Entwicklung der Dolinen sowie mit der Rolle der ökologischen Faktoren (I. GAMS 1974, P. GROSCHOPF—H. U. KOBLER 1973, K. PRIESNITZ 1968, S. T. THURDGILL 1977, J. NICOD 1976). Auf die Systematisierung der Dolinen dagegen spezialisieren sich nur wenige W:ssenschaftler. Hier seien die genetischen Klassifizierungsversuche der sowjetischen Forscher D. S. SOKOLOW (1962), A. MAXIMOWITSCH (1963), G. W. KOROTKEWITSCH (1970) und N. A. GWODSDETZKI (1972) erwähnt.

Auch ungarische Forscher haben die traditionelle, bzw. zeitgemässe Erklärung der Karstentwicklung in mehreren Phasen weiterentwickelt.

J. CHOLNOKY (1916) z. B. stellte auch in internationaler Relation als erster fest, dass sich die Kalksteinoberfläche nur sehr langsam zersetzt, was zur Bildung eigenartiger Oberflächenformen führt. Progressiv ist seine Feststellung, dass es zwischen Dolinen und Höhlen keinerlei Verbindung bestehe. Verfehlt ist jedoch seine Ansicht, dass die Dolinen durch einen infolge der Erweiterung von Karsthöhlen unter der Oberfläche und nachher der Verringerung der Gesteinsfestigkeit eintretenden ruckartigen Einsturz der Oberfläche entstünden. Seine Anhänger S. JASKÓ (1933) und J. KEREKES (1937) teilen die Ansicht CHOLNOKYs über die Entstehung der Dolinen.

In Ungarn wurde die zeitgemässe Erklärung der Karstentwicklung ab Mitte der 50er Jahre verbreitet. L. JAKUCS, LEÉL—ŐSSY S. und S. LÁNG analysierten die Gebilde der Karstentwicklung auf und unter der Oberfläche aus verschiedenen Perspektiven. Sie fassen die Dolinen als Lösungsgebilde auf. LEÉL—ŐSSY (1954) unterscheidet Einsturz- und Sinkdolinen. JAKUCS (1964) trennt diese je nach Niveau.

Bei der Ausarbeitung einer zeitgemässen Karstentwicklungstheorie widmet JAKUCS der Entstehung und Entwicklung der Dolinen grosse Aufmerksamkeit. Er ist der Ansicht, dass die Form der Dolinen eine Art Widerspiegelung der Anordnung ihrer Mikroklimaräume sei. Ferner erforschte JAKUCS die genetischen Eigenschaften der Reihendolinen und der sog. „individuellen" Dolinen, die nicht in Serien gehören, und untersuchte den Dynamismus der Dolinenbildung (1971).

Das Klima, insbesondere jedoch das Mikroklima wirkt sich auf die Entwicklung der Dolinen auf direkte, zusammen mit der Biosphäre und der Pedosphäre jedoch auch auf indirekte Weise aus (I. BÁRÁNY 1967, I. BÁRÁNY—K. KAJDÓCSY 1976, I. BÁRÁNY—G. MEZŐSI 1978). Das Makroklima bestimmt die mögliche Entstehung der Dolinen und die Intensität ihrer Entwicklung; mit der Biosphäre und Pedosphäre übt es aber auf die Dolinenentwicklung auch eine indirekte Wirkung aus.

Neben der entscheidenden Rolle des Klimas kann die Qualität des Grundgestein — vor allem seine Lösbarkeit und Schichtenanordnung — selbstverständlich ausch nicht ausser Acht gelassen werden. So z. B. kann die Verschmutzung des Gesteins durch Lehm oder Silikat die Lösungsintensität hemmen, die Gesteins-struktur (die Bröckligkeit, das Verhältnis der unlösbaren Rückstände usw.) dagegen verstärken. Obwohl die Dolinen in Faltengebirgen auch auf bröckligem oder horizontalen Kalkstein vorkommen, können in der Entwicklung der Formen auch die tektonischen Wirkungen Differenzen verursachen. Durch die Hebung, eventuell auch durch die Senkung der Karstoberfläche kann sich der Karstentstehungsprozess verstärken, gleichzeitig jedoch auch verlangsamen.

Die ausgeprägtesten Dolinentypen finden wir auf sanften Plateauabhängen in gehobener orographischer Lage, was zweifelsohne auch mit der Distanz der Denudationsbasis im Zusammenhang steht.

Wie wir darauf bei der Erörterung der Klimafaktoren bereits hingewiesen haben, spielen in der Dolinenbildung der auf der Gesteinsoberfläche entstandene Boden und die in ihm stattfindenden biologischen Prozesse, bzw. die Vegetation auf dem Boden eine bedeutende Rolle. Wir müssen mit der Ansicht von L. JAKUCS (1971) einverstanden sein, gemäss welcher „die Karstbildung im Grunde genommen eine Formwiderspiegelung der biologischen und chemischen Entwicklungsercheinungen der Pedosphäre auf dem lösbaren Grundgestein sei".

Auf Wirkung der vorhin erwähnten, sich je nach Gebieten ändernden Faktoren der Dolinenbildung sowie anderer — vor allem exogener — Faktoren kommen genetisch unterschiedliche Dolinentypen zustande.

In der Fachliteratur finden wir oft Klassifizierungen, die von dem Zusammenhang zwischen der gegebenen Raumform und der Dolinenentstehung ausgehen. Auf jeden Fall ist es richtiger, die Dolinen vom genetischen Aspekt zu klassifizieren, wobei man die Faktoren der Entstehung und Entwicklung in Betracht zieht. Selbst im letzteren Fall kommt es vor, dass die Forscher nicht eindeutig klare Typen beschreiben (H. CRAMER 1941, A. MAXIMOWITSCH 1963, G. W. KOROTKEWITSCH 1979), was auf die Wirkung der verschiedenen genetischen Faktoren zurückzuführen ist.

Auf genetischer Forschungsbasis unterscheiden wir auf den unbedeckten Karsten *Lösungs*-oder Korrosions-, auf den bedeckten Karsten *Schwund-* sowie auf beiden Oberflächen *Einsturzdolinen.* Unter diesen kommen in den Landschaften die Lösungs- und die Schwunddolinen in grosser Anzahl und in ausgeprägter Form vor. Vom Aspekt der exogener Wirkungen erscheinen die Einsturzdolinen nur zufällig.

Die *Lösungs- oder Korrosionsdolinen* sind die charakteristischsten Oberflächengebilde der Karstoberflächen. Diese Dolinenformen sind von den gemässigten Zonen bis zu den Tropen überall zu finden. In klassischem Sinne kommen die Lösungsdolinen am häufigsten dort vor, wo das Gestein unbedeckt und nur mit einer dünnen Bodenschicht überzogen ist. Ausser der Gesteinsqualität ist die Entsehung und Entwicklung, bzw. die Verbreitung der Lösungsdolinen selbstverständlich auch durch eine entsprechende Niederschlagsmenge und durch Temperaturfaktoren bestimmt.

Im Gegensatz zu den traditionellen Auffassungen sind wir der Ansicht, dass die Bioaktivität des Bodens, der das Gestein bedeckt, bwz. der Vegetation auf dem Boden eine grundlegende Bedingung der Entstehung und Weitrentwicklung von Lösungsdolinen darstellt (L. JAKUCS 1971, I. BÁRÁNY 1977, usw.).

Die frühere Auffassung, gemäss welcher in den arktischen und subarktischen, bzw. in den Hochgebirgsregionen die Korrosion durch die erhöhte CO_2-Lösungsfähigkeit des Kaltwassers intensiver und dementsprechend die Dolinenbildung schneller sei, ist nicht stichhaltig, da die die Lösungsintensität verstärkende Kohlensäure nicht etwa aus der freien Atmosphäre, vielmehr jedoch aus dem konzentrierten CO_2 der Bodenatmosphäre ins Lösungswasser fliesst. Auf diese Weise besteht die Möglichkeit, dass unter der Bodenschicht beinahe symmetrische Lösungdolinen entstehen.

Oft begegnen wir jedoch auch assymmetrischen Korrosionsdolinen. Die Mehrheit der Forscher führt diese Erscheinung auf die tektonische Preformation zurück. Unseren Forsuchngsergebnissen zufolge müssen wir jedoch wir die Erklärung der assymmetrischen Formbildung in den Mikroklima-, Vegetations- und Bodenunterschieden (auch Bodenleben) der Mikroräume von Dolinenseiten verschiedener Himmelsrichtungexpositionen suchen. Die Genetik der Lösungsdolinen kann also auf die blosse Tatsache der Gesteinslösung nicht reduziert werden; eine entsprechende Erklärung ist nur nach einer ausführlichen ökologischen Analyse möglich.

Unter den Lösungsdolinen sollen jene assymmetrischen Formen getrennt untersucht werden, wo die periodische Erhaltung der Schneeflecken bei der Lösung entscheidende Rolle spielt. In Hochgebirgsgebieten schmilzt der Schnee in einer günstigen (nördlichen) Exposition im ganzen Jahr nicht. In diesen Regionen ist die Gesteinslösung stärker als auf anderen Dolinengebieten. Hier kommt dem biogenen Faktor gar keine — oder höchstens eine minimale Rolle zu. Die Erklärung ihrer Entstehung ist mit der traditionellen Auffassung verwandt.
In Ungarn sind die meisten Dolinen Lösungsdolinen.

Die *Schwunddolinen* kommen auf Gebieten vor, die mit solchem Gesteinsmaterial bedeckt sind, das eine Karstbildung nicht ermöglicht. Unter dieser Gesteinsdecke entstehen die Dolinen durch subkutane Lösung. Die Lösung des Kalksteins erfolgt punktweise unter jenen Stellen, wo das Wasser eindringt. Nachher kommt es zur stufenweisen und sich wiederholenden Nachsinkung der Oberfläche.

Ähnliche Dolinen sind auch auf Salz,- Gips- und Dolomitgrundgestein häufig zu finden. Die Forscher beschrieben viele Dolinen dieser Art auf dem Gebiet des Schwäbischen und Fränkischen Alb, der Gipskarste in Podolien und der Appeninen. CVIJIČ und KATZER beschrieben die in den Dinarischen Karsten vorkommenden Schwunddolinen; ihre Forschungsergebnisse sind jedoch in Vergessenheit geraten. Unlängst haben P. GROSCHOPF und H. U. KOBLER (1973) diese Dolinen eingehend untersucht.

Die Ähnlichkeit ist jedoch nur eine morphologische und keine morphogenetische. Die Grundlage der Dolinenbildung ist zwar sowohl bei dem Steinsalz als auch beim Gips die Lösung, doch müssen wir die Karstformen dieser Gesteine von den Lösungsdolinen des Kalksteins unterscheiden, da in ihrer Entstehung der biogene Faktor keine Rolle hat.

Die dritte grosse Gruppe sind die *Einsturz-* oder Gravitationsdolinen. Diese Formen entwickeln sich dort, wo unter der Oberfläche grosse Höhlen zu finden sind. Nach der Verringerung der Gesteinsfestigkeit stürzt die Höhlendecke ein. Die Wände bleiben im allgemeinen steil stehen. Die Einsturzdolinen sind von den subarktischen Regionen bis zu den Kupkarstgebieten der Tropen überall zu finden, jedoch nur sporadisch; in ihrem Vorkommen können wir keine Regelmässigkeit entdecken.

Die drei Haupttypen erscheinen auf Karstoberflächen auch in verschiedenen Übergangsformen. Sehr oft begegnen wir einer Vereinigung der Lösungs- und Einsturzprozesse. Die Schwemmlanddolinen vertreten eine spätere Entwicklungsphase. Wenn wir von entschiedenen Dolinenentwicklungszyklen in dem DAVISschen Sinne auch nicht sprechen können, doch soll man die Schwemmlanddolinen als reife Reliefs betrachten.

Bei den beiden grundlegenden Dolinentypen (Lösungs und Schwunddolinen) ist die Korrosionstätigkeit dominant. Dazu kommt im Laufe der Weiterentwicklung der Doline oft auch eine areale Abspülung. Durch die Infiltration können auch gewisse

Materialumordnungen erfolgen, die auch als Faktoren in den Suffosionsprozessen auftreten. All das gehört jedoch in den Bereich der Umgestaltung und nicht etwa in den Themenkreis der Entstehung.

Die Korrosions-, Gravitations- und Suffosionsprozesse können einander verstärken oder eben schwächen und dabei die Erosion ober Akkumulation der negativen Form beschleunigen, den genetischen Grundtyp jedoch auf keinen Fall ändern. Selbstverständlich kommen innerhalb dieser drei Haupttypen noch mehrere Untertypen vor, die das eine oder das andere bestimmende Merkmal der Haupttypen tragen.

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UMWELTSBEWERTUNG II. DER BEGRIFF DES UMWELTSPOTENTIALS UND EINIGE THEORETISCHE FRAGEN DER UNTERSUCHUNG

G. MEZŐSI

Eine der wichtigsten Fragen der geographischen Unweltuntersuchung ist die Qualifizierung der Kraftquellen, der Gegebenheiten, des Porentials dieser Umwelt. Heute haben wir die Grenze der *extensiven* Verwendung des Umweltpotentials erreicht, es ist also umso eher unsere Aufgabe die *intensive* Brauchbarkeit bestimmter Umweltregionen, deren Probleme und Möglichkeiten zu erforschen. Besonders wichtig ist die Untersuchung von Regionen mit engen, bwz. ungünstigen Gebenheiten, welche die Volkswirtschaft gezwungen ist in immer steigendem Masse in Anspruch zu nehmen, zur gesellschaftlichwirtschaftlichen Entwicklung des betreffenden Gebietes, im Interesse der dort Lebenden, zur Erhaltung, bwz. Steigerung ihres kulturellen- und Lebensstandards. Zur optimalen Umweltsausbildung einer Gebietseinheit benötigt die Volkswirtschaft immer mehr, und wie uns die Erfahrung lehrt, immer komplexere Informationsmengen. Doch hierzu braucht auch die Wissenschaft der Geographie ein einheitliches und umfassendes Konzept, die Ausarbeitung des Konzeptes gleichwertiger Methoden. Diese müssen nicht nur verwendbar sein zur Potantialbe)stimmung der einzelnen Regionen (natürlich, gesellschaftlich, wirtschaftliche Räumen) zur qualitativen und quantitativen Bestimmung ihrer Leistungsfähigkeit, sondersollen auch als Grundlage dienen, als Ausgangspunkt zur Ausarbeitung der möglichen Verwendbarkeit. Gleichzeitig wurde es zum wichtigen Ziel, dass diese Untersuchungen den Bedürfnissen der Praxis besser entsprechen sollen. Wir mussten nämlich erkennen, dass unsere bisherigen, die Umwelt klassifizierenden Untersuchungen — die allerdings zur Lösung wichtiger Praxisfragen führten — nur über viele Überlagerungen brauchbar wurden. Für die Verbraucher müssen wir unsere Ergebnisse viel verständlicher und zielgerichteter ausdrücken, wenn nötig „sollen wir direkt und aktiv in den Verlauf der Planung eingreifen (G. LÜTTIG 1975).

Im folgenden möchte ich das *sich in das Modell der Systemtheorie einfügende* Konzept des Umweltpotentials beschreiben:

Der Begriff des Umweltpotentials

Unter *Umweltpotential* verstehen wir jenes *System,* das sich aus dem Aufbau der Umwelt, deren dynamischen Veränderungen, Möglichkeiten ergibt (Kraftquellen, Gegebenheiten), die (in Zeit und Raum) zur Befriedigung gut abgegrenzter, gesellschaftlicher Bedürfnisse zur Verfügung stehen. Wie aus der Definition ersehbar, ist das Umweltpotential ein System der *Kraftquellen* (Ressourcen) *und Gegebenheiten.*

Untersuchen wir zuerst die Datenteile:

1.1 Wir betrachten als *Umweltgegebenheiten* jene *Menge* von meist stofflichen Eigenschaften der Umwelt, die, in weiterem Sinne gedacht, mit der produzierenden und verbrauchenden Tätigkeit der Gesellschäft in Zusammenhang stehen oder stehen können. Wie A. A. MINTS (1972) richtig darauf hinweist, verstehen wir darunter eine solche Erscheinungsgruppe, die zur Entwicklung der gesellschaftlich-wirtschaftlichen System wichtig ist,— was deren Tätigkeit betrifft- aber direkt nicht daran teilnimmt.

1.2. Die Gegebenheiten der Umwelt haben solch latente Eigenschaften, die im bestimmter industriellen, technischen Standard der Gesellschaft nutzbringend sind, also Kraftquellen werden können.

1.3. In den Kreis der Umweltgegebenheiten gehören auch jene *schädlichen Umweltelemente- und Erscheinungen,* welche oft eben die unerwünschten Reaktionen der Natur auf die Inanspruchnahme durch die Gesellschaft sind. Die Wirkung dieser ist wirtschaftlich negativ, doch mit dem entstandenen Schaden gut definierbar, d. h. mit dem Wert der Wiederherstellung. Als Gegenwert der Investition erscheint dies also bei der wirtschaftlichen Bilanz der Nützlichkeit.

2.1. Als *Kraftquellen der Umwelt* bezeichnen wir die *Gesamtheit* der Gegebenheiten, die bei *bestimmtem* gesellschaftlich-wirtschaftlichem Standard (Technik) die Notwendigkeiten der Produktion und des Verbrauches aufgewiesen haben und nutzbringend gestalteten.

2.2. Eines der wichtigsten Kriterien der Kraftquellen ist die *Nutzbarmachung.* Diese setzt immer bestimmte Stoffe und Erscheinungen, Gegebenheiten der Umwelt voraus, deren *Konzentration,* bzw. *Intensität.* (W. GRINGMUTH 1974, 1976).

2.3. Das Ziel der Nutzbarmachung der Kraftquellen — inbegriffen auch die damit auftretenden Kosten — ist immer die Sicherung des Nutzens für die gesellschaftliche Produktion. Also müssen wir die Kraftquellen der Umwelt als *wirtschaftliche* Kategorie behandeln. Doch hängt die Nutzbarkeit der Kraftquellen von; mit der Zeit sich schnell verändernden, wirtschaftlichen, technischen Bestimmungen ab. Diese Bestimmungen grenzen auch mehr ober weniger den Kreis der Umweltskraftquellen ab. Hiervon abgesehn, haben wir natürlich bestimmte Verlaufe und Stoffe der Umwelt als Kraftquellen anzusehen, ob diese nun im gegebenen Geniet nutzbar gemacht werden oder nicht. (z. B. nicht geförderte Energieträger, ungenutzte besondere Landschaftgenheiten usw.) Wegen ihrer zeitlich veränderlichen Nützlichkeit, bzw. Wirtschaftlichkeit betrachten wir die Kraftquellen als eine *historiche* Kategorie.

2.4. Es sind viele Arten der Klassifizierung der Umweltkraftquellen bekannt. (A. A. MINTS 1972, G. LÜTTIG 1975, E. NEEF 1971, D. GRAF 1977). Da wir eine objektive Aufteilung nicht machen können — sind unserer Meinung nach jene Aufteilungen die besten, welche bei der Bewertung, der Qualifikation der Umwelt am geeignetsten sind (PÉCSI, M. 1979). Es ist nicht sicher, dass diese der Wirklichkeit am nächsten kommen, aber modellstattlich sind sie enthalten. (Aehnlicherweise enthält auch die systemprinzipielle Struktur der geographischen Umwelt nicht alle Zusammenhänge, da man nicht alles in Systemskategorien ausdrücken kann.)

2.5. Die Kraftquellen der natürlichen und der Sozioökonomischen Umwelt stehen in engem *Zusammenhang zueinander,* bilden ein *System.* Deshalb können wir nicht einer Meinung sein mit jenen Ansichten, die den Kreis der Kraftquellen auf nutzbare minerale Rohstoffe oder auf Energieträger abgrenzen, obzwar zweifelsohne eben diese in unseren Tagen die gesuchtesten Potenzien bilden.

3.1. Dei wichtigsten Unterschiede der Kraftquellen und der Gegebenheiten der Umwelt können folgendermassen zusammengefasst werden:

a) Nehmen sie direkt Teil an der Entwicklung der gesellschaftlichen Produktion, am gegebenen Standard der menschlichen Produktivität und Verbrauchstätigkeit? (Die Frage von der praktischen Seite betrachtet.)

b) Im Gegensatz zu den Gegebenheiten verändern sich die Kraftquellen *dynamischer,* können sich *regenerieren, erschöpfen.*

3.2. Das Verhältnis, der Unterschied zwischen den Kraftquellen und Gegebenheiten verändert sich in Raum und Zeit. Mit der Entwicklung der Gesellschaft (industriell, technisch), mit der intensiver werdenden Nutzbarmachung der Umwelt *erweitert sich* der Kreis der natürlichen Kraftquellen — doch gegenwirkende Veränderungen können dies auch verzerren — so wird die „Entfernung" zwischen ihnen immer *enger,* immer mehr Gegebenheiten werden zu Kraftquellen.

4.1. Auf Grund der einleitenden Definition über das System der Kraftquellen und Gegebenheiten, steht das *Umweltpotential* zur Gefriedigung gewisser gesellschaftlicher Notwendigkeiten zur Verfügung. Wie aus dem in Punkt 1. und 2. Beschriebenem hervorgeht, ist der Inhalt des Potenzials aus der Struktur und den Veränderungen der geographischen Umwelt abzuleiten, unter diesen die bestimmende gesellschaftliche-ökonomische Seite.

4.2. Das Umweltpotential ist keine statische Kategorie. Durch die Entwicklung des Stoff- und Energietausches der Umwelt, d. h. fliessend ruhende und sich in sehr verschiedener Zeit abspielende Entwicklung, erneuert sich das Potential, oder es verändert sich *dynamisch in Zeit und Raum.* Das bedeutet einesteils, dass es sich von Zeit zu Zeit abändert, und zwar der materiellen, technischen, gesellschaftlichen Entwicklungsstufe der Volkswirtschaft entsprechend, sowie dem Masse der „Nutzbarmachung" der Umwelt. Daher kann das Potential sinngemäss nur für ein absehbares Intervallum angegeben werden (Prognose). Andernteils kommt die Dynamik auch in der Reproduktion, bzw. in der Regeneration zum Ausdruck. Hindern dies mehrere, durch die intensive Nutzbarmachungstätigkeit verursachte, potentialschaffende (diskontinuierende) Elemente, welche sich in der gegebenen Zeitspanne nicht, ober nur in geringem Masse regenerieren. (H. ROSS—W. GRINGMUTH 1974, ROSS 1976). Solche sind unter anderem jene Potentialeigenschaften, die sich an fossile Stoffe und an Energieträger binden. Unsere 1. Zeichnung zeigt das Schema der zeitgebundenen Veränderungen des Potentials, nach G. HAASE (1978).

4.3. Das Potential wird zum Wert sobald es in die Sphäre des menschlichen, gesellschaftlich-wirtschaftlichen Seins eintritt. D. h., dass der Wert immer das Vorhandensein des Verbrauchers voraussetzt ,denn der durch das Potential „gebotene" Nutzen ist nicht einfach der aus der Umwelt, bwz. deren innerer Struktur der „von selbst gegebene Mitgänger". Folglich muss das Potential auch als *ökonomische Kategorie* analysiert werden, was unumgänglich macht, dass die Potentialuntersuchungen derartige quantifikale Ergebnisse bringen, die dann den Ausdruck ihrer Werte ermöglichen.

4.4. Heutzutage *zwingt* uns der Bedafr der gesellschaftlichwirtschaftlichen Entwicklung zur intesiven Ausnutzung des Umweltpotentials, dessen in Rechnungstellen und seiner Bewertung. Die in der Umweltforschung bisher erreichten theoreti-

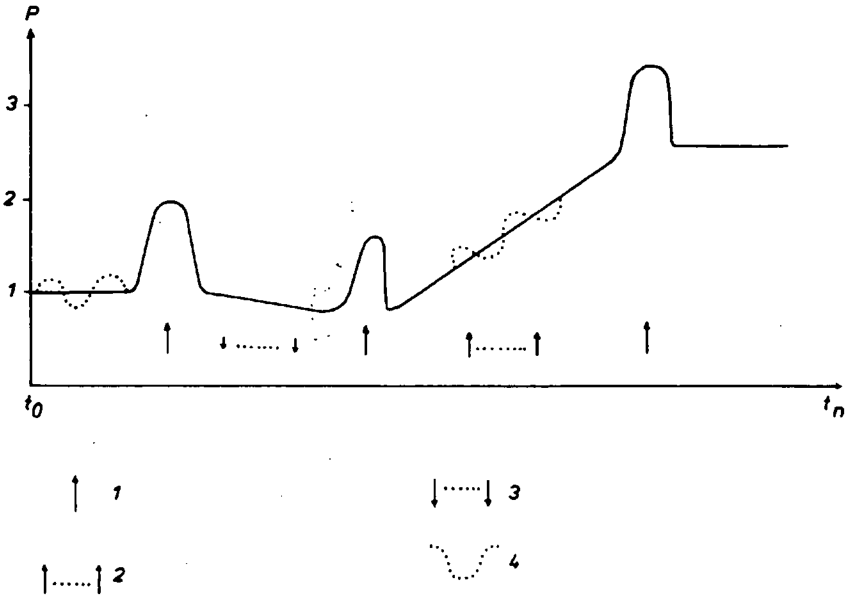

Abb. 1. Das Thema der zeitlichen Veränderung des natürlichen Potentials. (nach A. HAASE 1978).
P — Der relative Qualitätswert des natürlichen Teilgruppenpotentials
1 — Zeichen der sich binnen kurzer Zeit abspielenden (reversiblen) Veränderung (Reproduktionswirkung)
2 — Zeichen der ständigen Veränderung des Potentials (Erweiterte Reproduktionswirkung)
3 — Zeichen der ständigen Veränderung des Potentials (Sich vermindernde Regenerationswirkung)
4 — Kurzzeitliche Pendel (z.B. je nach Jahreszeit, periodische Veränderung) welche den Hauptkarakter der Potentialveränderungen nicht abändern

schen und systematischen Ergebnisse ermöglichen aber noch keine vollkommene und umfassende Untersuchung, denn die Nutzbarmachung des Potentials berührt doch in irgeneiner Form die *ganze* geographische Umwelt, überlagert beeinflussen die so entstandenen Wirkungen das Potential selbst.

Es ist also zweckmässig die *verschiedenen Gruppen* des Potentials und die ihnen eigenen *sich aufeinanderbauenden Formen* zu behandeln — aus systematischer und praktischer Sicht — entsprechend den Bedurfnissen, bzw. den Nutzbarmachungen. Die prinzipielle Grundlage hierzu ist, dass das Inbedarfnehmen der Umwelt sich im allgemeinen nicht auf ihr Ganzes erstreckt, sondern zum Teil auf eine hervorgehobene ihrer Gegebenheiten, teils auf ein solches System dieser Fakten „Kettenerscheinungen", in welchem die einzelnen Kraftquellen und Gegebenheiten mit unterschiedlicher Betonung vertreten sind.

a) Partielle Umweltpotentien

Deis sind die ökologischen Fakten, die die einzelnen partiellen Kraftquellen und Gegebenheiten auf ihrer Ebene qualifizieren, je nach den einzelnen, bestimmten wirtschaftlichen Bedürfnissen. Letzteres erscheint überflüssig, denn gewisse Kraftquellen und Gegebenheiten binden sich von selbst verständich an je einen bestimmten Zweig der Nutzbarmachung, z. B. Boden und Landwirtschaft, oder brauchbare mineralische Rohstoffe und Bergbau, doch wirt die Frage sogleich weiger einfach, wenn wir z. B. Berg- und Tal- oder hydrologische Gegebenheiten, bzw. Kraftquellen betrachten. In diesem Sinne können wir von Berg- und Tal-oder Rohstoffpotential sprechen. Mehrere Wissenschaftler (z. B. H. NEUMEISTER 1977, J. DEMEK 1978, K. V. PASKANG 1974 usw.) verstehen unter dem Begriff des partiellen Umweltpotentials die Gesamtheit aller solcher Möglichkeiten, welche diese (z. B. Berg-und Tal) der Gegesellchsaft bieten. Nach Punkt 4.3. kann dies als qualitative Bewertung der Zusammensatzteile betrachtet werden, was zu quantitativen Untersuchungen unbedingt notwendig ist, was aber die dem Begriff Potatial gegenüberstehenden, weiteren Kriterien nicht befriedigt.

b) Teilgruppen-Umweltpotential

Infolge der Veränderung des zeitlichen Bedarfes erstreckt sich die gesellschaftliche Nutzbarmachung — selektiert — auf bestimmte Gruppen der Umweltfakten, innerhalb welcher die verschiedenen Zusammensatzteile verschiedenes Gewicht erhalten. Diese Kategorie ähnelt in gewissem Masse dem Zweigpotential nach URBANEK, M. (1978), bzw. dem teilweisen natürlichen Potential nach G. HAASE (1973, 1976), es werden Rohstoffpotential, Bebauungspotential, Rekreationspotential, Wasserpontential usw. voneinander unterschieden. Den hauptsächlichen Unterschied sehen wir darin, dass in der hier einzeln beschriebenen Vorstellung die Elemente des gesellschaftlich-wirtschaftlichen Systems eine wichtige Rolle bekommen. Nach der folgenden Formel können wir uns dem Teilgruppen-Umweltpotential nähern:

$$Pi(x) = R\{\bar{E}(x) + \bar{A}(x)\}, \text{ wo}$$

$$\bar{E} = E_1 + \ldots + E_k^* + E_l^* + \ldots E_n \text{ und } \bar{A} = A_1 + \ldots + A_k^* + A_l^* + \ldots + A_n$$

weiters
E_j, A_j — Kraftquelle, Gegebenheit; E_j^*, A_j^*, — gewichtigte Werte; Pi — der gesellschaftlichen Forderung entsprechende nutzbare Werte.

c) Integriertes Umweltpotential

Diesen Begriff verwenden wir im *engeren* und im *weiteren* Sinne. Im engeren Sinn bedeutet dies die Potentials der einzelnen Untersysteme, im weiteren Sinn geben die Potentialwerte das zusammengefasste Potential der ganzen untersuchten Umwelt, d. h., dem Vorangegangenen nach ist $P(x) = R\{Pi\}$. Die so entstandenen Werte können zugleich als die „Gebiets"-Werte der Region aufgefasst werden. Das integrierte Umweltpotential gibt nicht das einfache Kataster der Kraftquellen und Gegebenheiten des Gebietes, es ist also nicht die Summe der vorigen Potentialformen, sondern ein System, in welchen quantitativ und qualitativ deren Zusammenhänge und Aufeinanderwirkungen bewertbar werden. Demzufolge ergibt sich die Möglickeit zur Planung der rationellen Verwendung des Potentials. Die grösste Schwierigkeit bei der Bestimmung der Werte des integrierten Umweltpotentials liegt Finden der gemeinsam bezüglichen Grundlage. Bei der Analyse des natürlichen Umweltpotentials (nach G. HAASE 1978, „allgemeines" natürliches Potential) wird häufig eine Methode verwendet, die die Potentien als Stoff-und Energietausch-Verlauf behandelt (z. B. E. NEEF 1969, E. P. ODUM, 1971, H. ELLENBERG 1975, D. L. ARMAND 1975). Nach E. NEEF (1969) kann das allgemeine, natürliche Umweltpotential (P) in folgender Formel erfasst werden:

$$P = G + R + B + K$$

Es bedeuten:

G= die Umstandsenergie der Stoffe

R= die ständige Energieaufnahme des Gebietes durch den Sonnenschein

B= die in den Stoffen durch kosmische, geologische, biologische und bodenwissenschaftliche Verlaufe angesammelte (latente) Energie

K= die in die stofflichen Gegenstände der natürlichen Umwelt, durch verschiedene Arbeitsgäne eingebaute Energie.

Die so zu verstehenden Potentien haben einfachen und zugleich komplexen inhalt, nur sind sie im praktischen Leben schwer verwendbar. Die Untersuchungen eignen sich vielmehr für die Ausarbeitung der Umwelt, bzw. deren einzelner Geosysteme dynamischer Entwicklung, wie das auch die erlangten Ergebnisse der auf Makro- und Mikro-Ebene unternommenen Analysen beweisen. (NEEF 1979, FORESTER 1978, bzw. ARMAND 1976, SOCHAVA 1975).

4.5. Die im Vorangegangenen bestimmten Potentialformen haben verschiedene *taxonometrische* Einheiten. In der in *engerem* Sinne in Naturpotential) genommenen, integrierten Form des Umweltpotentials ist als solche Kategorie der von MAROSI—SZILÁRD (1963) definierte ökopottyp zu betrachten.

Von anderem Standpunkt aus untersucht, gehőren aus der Sicht der Potentien, Landschaften und „konkrete Umwelten" in verschiedene *Typen* (MAROSI 1980). Die *allgemein* gültige Benennung sowohl der taxonometrischen, als auch die der Typen ist eine wichtige Aufgabe, doch auf der Ebene unserer jetzigen Erkenntnisse ist letzteres nicht als die Hauptfrage in der Potentialforschung zu nehmen.

5.1. Eine der wichtigsten Fragen ist die Untersuchung der natürlichen Produktionsbedingungen im Rahmen der Wirtschaftsgeographie und der Volkswirtschaftswissenschaft. Obzwar diese mit den Potentien im Zusammenhang steht — denn sie bedeutet ja die Summe solcher prinzipiellen Potentialschaffer, welche die *notwendigen* materiellen Bedingungen der Produktion und des Verbrauchers ausmachen — müssen wir sie dennoch als abweichenden Begriff behandeln. Die natürlichen Produktionsbedingungen sind durch die gesellschaftlichen Wirkungen veränderlich, in scheinbar sich vermindernden Rolle erfüllen sie die *Funktion eines Katalisators* und sind verhältnismässig unabhängig von der Brauchbarkeit. (In Wirklichkeit ist das nicht eindeutig, es spiegelt eher das bessere Erkennen der Natur.) Die natürliche Bedingung der Produktion ist eindeutig eine *gesellschaftswissenschaftliche* Kategorie.

Einige prinzipielle Fragen der Potentialforschung

6.1. Das Endziel der Umweltpotentialforschung ist die Steigerung der Wirtschaftlichen Tätigkeit (produzierend und nicht produzierend), die Schaffung der optimalen Umweltwirtschaft. Wichtige Aufgabe sind die gesellschaftlichen Massnahmen, die wirtschaftspolitischen Entscheidungen und die Verwirklichung der zwischen den Umweltpotentien bestehenden, gegenseitigen Aufeinanderwirkungen.

6.2. Das Ziel der Forschung und der Prognosebedarf der Potentien erfordert, dass, über die brauchbaren Kraftpuellen hinaus, die Untersuchung sich auch auf die Bewertung der Umweltgegebenheiten erstecke. Nur mit der komplexen Analyse dieser kann die Ausarbeitung dieser Kraftquellen-Gegebenheiten-Systeme wirklich ermöglicht und in die wirtschaftlichen Pläne miteinbezogen werden.

6.3. Die Analyse, die Forschung rationeller Brauchbarkeit kann bei jeder der Potentialformen von einem anderen Standpunkt aus geübt werden. Unter diesen muss zweifelsohne die *Gesamtheit* der ökologischen und ökonomischen Aspekte die führende Rolle spielen (J. LEMESEV 1978). Daneben erfordern die technischen, die Naturschutz- und politischen Gesichtspunkte gesonderte Verhandlungen. Die schwierigste Aufgabe besteht in der Bewertung des wirtschaftlichen (quantitativen) Potentials, denn heute verfügen wir noch über keine prinzipiell grundlegende und gut brauchbare Methode (obzwar dies doch eine der am ehesten auf der Hand liegenden und meistperspektivischen Arten wäre). Eine ernste prinzipielle Schwierigkeit liegt in der Bestimmung der Werte der Potentien, im Sinne der politischen Wirtschaftwissenschaft, oder der Bewertung des Anteils am Nationalvermögen (BORAI, Á. 1977). Und dies umso eher, als mehrere Kraftquellen und Gegebenheiten wirtschaftlich (pekuniär) nicht bewertbar sind. So wird die Wichtigkeit der qualitativen Bewetrung des Potentials und seiner führenden Rolle verständlich.

Unseren jetzigen Kenntnissen entsprechend sind zwei qualitative Richtungen zu unterscheiden, die auf ökologischer Grundlage ruhend, *raletive* Werte aufzeigen. Die eine arbeitet auf Grund der vom Standpunkt der Potentialtypen aus dominierenden Fakten gewichtigter Werte (HAASE, HRAEOWSKI, PÉCSI, CAHA, TRICART, YOUNG), die andere versucht aus der Summe der elementar potentialschaffenden Werte (z. B. ökologische Fakten) die Grösse der Potentien zu bestimmen (KOZUCHOV, SPORBECK, ZAYCEV).

Bei der Untersuchung der Potentien spielt das Potential der natürlichen Umwel eine ihm eigene, hervorragende Rolle. Das ergibt daraus, dass die natürlichen Kraftquellen die wichtigste stoffliche Basis der Produktion bilden und dass sich jedwede produktive und nich produktive Tätigkeit irgendwie an die einzelnen Komponenten der natürlichen Umwelt bindet.

6.4. Eine oft gestellte Frage ist, in welcher regionalen Einheit wir die Qualifizierung der Potentiale vorgenommen haben. Im Zusammenhange hiermit bieten sich zwei, abweichende, auf prinzipieller Grundlage ruhende Lösungen. Bei der ertsen ist die Aufzeichung (Kartographie) der Potentialen des Gebietssystems das Ziel. Dies kann analog wie die wirtschaftliche, bzw. natürliche geographische Regionierung geschehen. Es ist zweckmässig hierzu neutrale Gebietseinheiten zu wählen (z. B. geometrische, verwaltungsmässige). Hier liegt die Betonung auf der Bereinigung des Potentials bei den Gebietsunterschieden. Bei der zweiten Lösung hingegen analysieren wir die verschiedenen wirtschaftlichen und naturgeographischen (regionalen) Einheiten, nach dem Gesichtspunkt ihrer Funktion, bzw. des Typs, der sich am stärksten an die Verwendbarkeit knüpft.

Die Lösungen können sich natürlich abändern, je nach den Massverhältnissen und der zur Verfügung stehenden Datenbasis.

6.5. Die Potentialuntersuchungen übertreten nicht nur die Grenzen der Geographie und der Naturwissenschaften, deshalb erfodern sie die Zusammenarbeit von Fachleuten verschiedener Wissenschaftszweige. In einem solchen Forschungssystem würde die Geographie, dank ihren Karakterzügen und Methoden die ihr eigene koordinierende Rolle spielen.

Einige ausländische Methoden der Umweltqualifikation könnten auf unsere heimatlichen Verhältnisse adatiert werden. Gewisse Teile könnten in internationalem Rahmen gelöst werden, aber die inhaltliche Verwirklichung könnte nur innerhalb der heimischen Forschung geschehen.

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